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With regards to short distance transport systems this study examines the requirements of different groups of people.

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EVALUATION OF SHORT-DISTANCE
TRANSPORT-TECHNIQUES

October 1976

Intermodal Consideration and Evaluation of Short-Distance Transport Techniques

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SUMMARY:

The CCMS/NATO project is divided into four parts:

- (1) - Requirements of Short-Distance Transport Systems
- (2) - Inventory
- (3) - Assessment and Comparison
- (4) - Conclusions.

Different groups of people have different requirements with regard to short-distance transport systems. The study examines the various requirements from the points of view of

- passengers,
- town and traffic planning
- community/environment, and
- public transport operators.

In each of the areas discussed, judgment criteria can be defined for the various requirements. For instance, one of the requirements of the community/environment sector is the reduction of air pollution. A sub-aspect of this requirement is exhaust gas emission. It can be transformed into a judgment criterion by specifying the type of exhaust gas to be considered (e.g. NO_x) and by fixing the desirable minimum as well as the maximum permissible values for emission (of NO_x). Thus the emission of NO_x is one "indicator" for the criterion exhaust gas emission. Each short-distance transport system produces a different contribution to this indicator (emission-level) which is used in the assessment.

The inventory is based on three elements:

- (1) - brief system descriptions
- (2) - description of existing transport systems and their future development, and
- (3) - description of new transport systems

SUMMARY AND RECOMMENDATIONS
# of the
CCMS/NATO PROJECT: INTERMODAL CONSIDERATION AND EVALUATION OF SHORT-DISTANCE TRANSPORT TECHNIQUES

The CCMS/NATO project "Intermodal Consideration and Evaluation of Short-Distance Transport Techniques" is part of the CCMS Pilot Study on "Urban Transportation". It was carried out under the leadership of the Federal Ministry of Transport of the Federal Republic of Germany. The work of the study group was coordinated in the course of several meetings in which representatives of the following countries participated:

- Belgium
- Canada
- France
- Italy
- Netherlands
- United Kingdom
- U.S.A.

The working papers sent out to the participants before the meetings were prepared by the SNV - Studiengesellschaft für Nahverkehr (Short-Distance Transport Studies Corporation) - Hamburg, on behalf of the German Federal Ministry of Transport. Members of the Corporation took a prominent part in the ensuing discussions.

The assessment and comparison of short-distance transport systems can be effected by means of formalised assessment methods or by verbal comparison. Section 1 of chapter 3 outlines the three assessment approaches:

- cost-benefit analysis
- cost-effectiveness analysis
- multi-attribute utility analysis.

Since different groups of persons attribute different importances to the benefits/effectiveness, section 2 describes and gives examples of how they are determined. In the following section, short-distance transport systems are examined from the point of view of the different groups of persons with respect to the degree of fulfilment of the various assessment criteria. To permit technical differences between transport systems to be adequately included in an assessment, a special section of this chapter outlines individual component developments.

The chapter conclusions describes cost developments of transport systems.

Furthermore, it examines the prospects of new-type transport systems which are determined by

- the further development of existing systems
- the development of costs
- an estimate of the benefits arising from new systems for the different groups of people concerned (e. g. users, the general public).

Within the framework of the available data, the study puts forward general statements on costs as well as statements on

Questionnaires for system data have been developed and annexed to the section containing the system descriptions. The explanatory notes attached describe which data and how to fill them in, with a view to ensuring the compatibility and comparability of the data provided. All short-distance transport systems are divided into eight groups. The characteristic features of the different groups are briefly described.

The section dealing with the description of existing short-distance transport systems and their future development covers rapid transit railways, tramways, motor buses as well as the system groups dual-mode and dial-a-bus; the difference between the latter two bus systems and the conventional bus consisting, in the first case, in an additional technical component (track-guidance), in the second case, in the operating concept (possibility of ordering or calling a bus). → go to p. 41

One characteristic feature of new short-distance transport systems is automated operation, i.e. largely without driving personnel. No less typical are new technical components e.g. for support and guidance techniques, and a separate right-of-way, indispensible for automated operation.

Special-type railways, ships, boats, and helicopters have not been considered due to their limited importance for urban mass transport. Continuous conveyor systems are usually designed for distances of around 100 m and therefore must be regarded primarily as complementary components of other major systems, e.g. in stations.

the prospects for further technical development and estimated benefits. These statements permit to make global judgments on individual system groups, following the break-down given in the inventory chapter.

The study does not include a complete cost-benefit analysis - mainly because of the difficulties connected with cost quantification. In a comparison on an international scale, cost data can be used only with utmost care, owing to the difficulties arising in connection with exchange rates, time differences (data supplied by manufactures!) or because only estimated values are available (for new developments).

Furthermore it may be assumed that the importance attributed to the various assessment criteria will also differ from country to country. Therefore, any attempt to determine these importances on an international basis would inevitably level out existing differences and negatively affect the significance of these values for individual countries.

In conclusion, the study group agreed to put forward the following recommendations concerning existing and new short-distance transport systems:

RECOMMENDATIONS:

If public transport is to be a true alternative to private transport, it must be able to meet certain standards in respect of travel speed, frequency and comfort which at present are met by only few public transport systems. Therefore, sustained efforts to promote and enhance public transport should be part of any policy aiming at an improvement of traffic conditions in local communities.

For the realisation of such a policy, it is recommended that the following points be considered:

1. The efficiency of current operational systems should be improved to the maximum extent possible by a better operation and integration of existing public transport systems.

2. Travel times can be significantly reduced only if separate rights-of-way are provided for public short-distance transport and private transport. In this context, attention should be paid to the fact that new as well as conventional systems with an exclusive right-of-way

2.1 cause relatively high initial and subsequent expenditure

2.2 necessitate a high traffic volume in order to keep costs per passenger-km relatively low.

3. Underground railways and rapid transit railways should be considered as likely alternatives for highly congested and trafficked routes, especially where the traffic volume is very high. Any decision in this context should, of course, be supported by a sound cost-benefit/effectiveness analysis.

4. For medium and higher traffic volumes, conventional tramways sharing their rights-of-way with private traffic cannot be favoured. Where tramways are used in such environments, they should be upgraded and consideration given to their substitution by rapid transit systems.

5. Because the bus offers the greatest opportunity of universal utilisation at low costs, it may be assumed that - under present conditions - the bus is and will continue to be the best suited mode of transport to meet present and future short distance transport and urban requirements, either alone, or where appropriate, such as in larger cities and metropolitan areas, in combination with rail transport systems. This applies despite the low attractiveness attributed to buses (similar as to tramways) by the users. For this reason, and in view of the great scope for improvement, the bus is considered to have the relatively best development prospects and the further development of the bus appears particularly promising. Attention should also be given to the further development of dual-mode and dial-a-bus systems.

6. It is particularly important that the promotors of new transport systems reduce the capital and operating costs in order to reach an economically attractive alternative to conventional systems.

7. Only systems with their own exclusive right-of-way (i.e. without grade level crossings with other transport systems) can operate fully automated. For systems development a fully automated operation has to be considered since it does not only offer advantages with respect to safety, punctuality, energy savings etc. but also through savings in personal and personal costs.

8. In general, a combination of passenger and goods transport within the same system does not seem feasible in short-distance (urban) transport. However, some small cabin systems could be an exception, provided that certain additional investments and operational modifications are made.

9. The use of cost-benefit/effectiveness analyses in short-distance transport decision-making should be greatly increased and their results taken into account. In this context, it is important that such analyses should be conducted as a general rule, even though not all benefits effects can be adequately quantified or measured. Special attention should however be paid to bringing these non-quantifiable benefits (or costs) to the fore.

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1. Requirements of Short-Distance Transport Systems

1.1 Initial Situation

Because of certain inadequacies of present transport and traffic systems all parties concerned consider improvements in this sector to be desirable or even urgent. Traffic and transport planning cannot be limited to meeting the demands of private transport only. This is now also the opinion prevailing among the majority of private transport users. The reasons which impose certain restrictions of private transport especially in cities, are:

- environmental nuisance (exhaust gases, noise, waste),
- low rate of safety (human inadequacy),
- high space and surface requirements,
- low capacity per width of traffic lane,
- high mileage costs.

(The order in which these factors are listed gives no indication of their order of importance). However, in areas with a high rate of private traffic, environmental nuisance as well as space and surface requirements will be of greater importance than other factors.

In recent years, traffic planners and politicians have developed a number of concepts which might serve as guide-lines for the solution of short-distance transport problems:

- functional division between public and private transport in large cities, assigning
  - priority to the private automobile in the outlying areas;

  - equal priorities to private transport and public transport (e.g. bus services) as feeder lines to the high-capacity transport systems (e.g. urban rail system), in the suburban area (area between the outlying districts and the city);
  - priority to public transport in the inner city area;
- restriction of private transport usage while promoting and improving public transport in the inner city areas of medium-sized and small towns or in certain activity centres (university campuses);
- moratorium on the so-called "automobile-suited" cities.

One of the reasons calling for an improvement of the standard of public transport in industrialized countries is the universal high standard of living enjoyed by a high percentage of the population also in respect of private motoring. Several factors explain the present high rate of private car usage: the greater freedom of disposition in terms of time and place afforded by the private car which public transport is not able to match to the same degree; but also dissatisfaction on the part of the traveling public with certain inconveniences, such as low traveling speeds, transfers, long walking distances etc.

All further and new developments in the public transport sector are primarily keyed to better meeting the requirements of the users than in the past. However, these may in some instances conflict with the requirements of the operators (of short-distance transport systems), as well as with the needs of society and the environment (e.g. traffic and city planning, political bodies, neighbourhoods). In a given situation, an elevated guideway could, for instance, improve travel time and punctuality and thus meet the interests of the users, as well as those of the operator, owing to greater reliability and savings in operating costs, but could nevertheless be objected to by city planners and neighbourhoods on the grounds of inadequate assimilation with the prevailing architecture, and aesthetic considerations.

1.2 Requirements and Judgment Criteria from the Passenger's Point of View

Some requirements are directly related to the nature of public transport usage. For instance, the availability of facilities for load and baggage carriage is usually only of importance to passengers using a system for shopping purposes. Unlike passengers traveling over short distances only, those traveling over a long distance tend to attach greater importance to seat availability, smooth operation, noise reduction etc.

For an overall assessment of short-distance transport systems it is necessary to take into account the total number of users at various times of service and at various levels of usage. This results in different weights being given to individual requirements:

- Among the various groups of passengers certain groups (e.g. children, old people, handicapped persons, foreigners, strangers, passengers carrying luggage or pushing prams) may have overriding requirements which are of little or no importance to the majority of other users.

- Seat availability is directly related to the amount of traffic carried. (At the point of origin of a route, seat availability is usually very high whereas it becomes very low at points capturing a large amount of traffic or during rush hours.) Passengers assess seat availability under the aspect of length of journey.

- Frequency of service may be adequate for the majority of passengers at peak traffic hours; however, the impression of unduly long waiting times during off-peak and post-peak periods (despite the lower traffic demands) tends to annoy or irritate most users.

The overall assessment of a short-distance transport system is therefore a combination of differently weighted individual judgments. Any specification of requirements and any assessment must therefore take into account a number of factors, according to their respective importance: service times, traffic volumes, nature of development and land use, climate, purposes of travel, mental and physical condition of the passengers.

1.2.1 Costs:

Passengers are primarily interested in low fares, especially for journeys requiring one or more transfers or for short distances.

The public transport fare per person and km is normally compared with the operating costs of the private car: but most car owners only take account of the fuel costs of their vehicle.

From the point of view of revenue, service-related fares (i.e. differentiation according to the length of the journey) would be desirable but in the majority of cases this is not possible, because they cause practical problems for operators and users (for them it is mainly a matter of information.)

There is, however, a good and justifiable case for differentiated fares for the various categories of users. For example, there should be differences between individual fares for casual travelers, and group or family fares, as well as fares for frequent journeys, i. e. commuter traffic.

Apart from the fares, passengers want to know the supplementary costs arising in connection with their journey, such as the price of the time-table or the schedule, the use of the telephone (for dial-a-bus services), parking fees, baggage lockers, taxi rides for connecting trips or for trips outside the operating hours of scheduled services.

1.2.2 Travel Time (Speed)

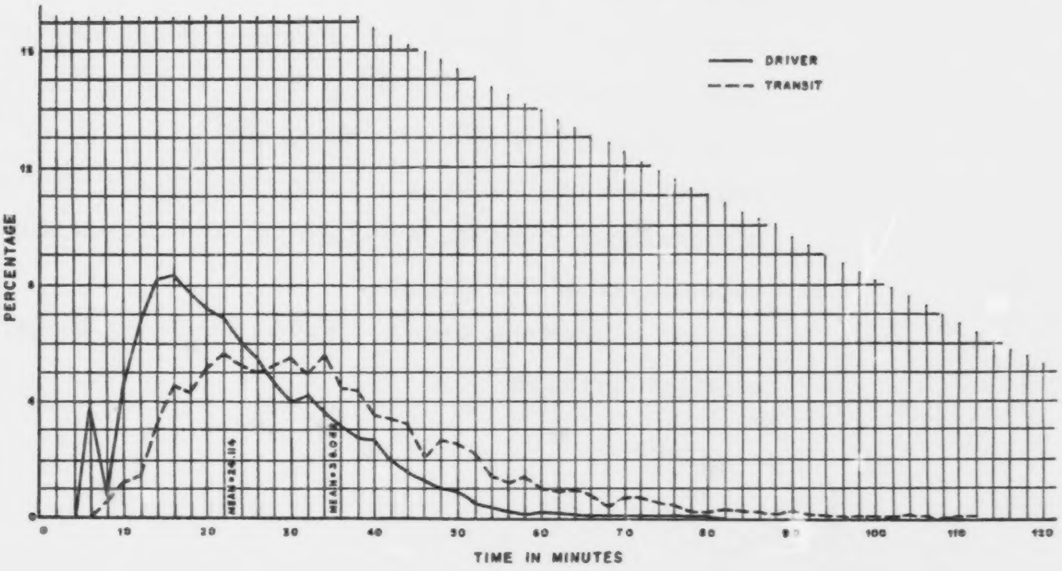
Travel time is made up of the following elements:

- walking time (time spent walking to and from the station or stop; and within stations to and from the vehicle);
- time spent on travel information and passenger handling;
- waiting time before vehicle departure, with or without vehicle delays;
- in-vehicle-time including
  - riding time,
  - stopping time at stations for boarding and alighting and scheduled waiting times (co-ordination of connecting services, time reserves),
  - time losses due to the traffic jams, technical breakdowns and inclement weather
- transfer time.

The accepted travel times are related to the length of the journey; however, there is a limit to the maximum acceptable travel time, which increases with the size of the city.

According to statistical data compiled in the Federal Republic of Germany [1], 33 % of the commuters in big cities of over a million inhabitants had in 1972 travel times of 60 minutes and more, whereas in cities between 100,000 and 200,000 their proportion is only between 5 and 17 %. Trip length distribution between private car and public transport is illustrated by the following diagram taken from a Canadian study of the Toronto conurbation [2].

TRIP LENGTH FREQUENCY DISTRIBUTION
24HR. HOME BASE WORK



The need for faster means of transport grows with increasing travel distance. Public transport users judge the travel times of public transport by the standards set by private traffic. Therefore, a reduction of public transport travel times is one of the conditions for a shift in the modal split in favour of public transport.

In most conurbations, the tangential services of public transport systems (suffering from low travel speeds owing to frequent interchange and transfers and long net-work related detours) are in need of improvement.

Priority measures for a reduction of travel times are:

- reduction of the obstructions for public road transport caused by private traffic (increasing the travel speeds);
- reduction of waiting times by increasing the frequency of services;
- reduction in the number of transfers consuming much time and physical effort (e. g. by increasing the number of cross-platform transfer facilities);
- regular and maximum use of the acceptable (in terms of passenger comfort) acceleration and deceleration capabilities of the system;
- lay-out of stations with a view to providing unobstructed straight footways.

1.2.3 Walking Distances (door to station; inside stations)

The total travel time from point of origin to destination should be as short as possible, therefore, the time spent walking to and from the station should not exceed an acceptable proportion of the total travel time. Speed of travel on a public transport system is a criterion determining the acceptance of different lengths of walking distances. Walking times which are equal to or longer than the travel time in a public transport system are acceptable only for certain distances (short distances), or for certain groups of passengers (handicapped persons or old people). The following factors influence directly or indirectly the acceptance of walking distances:

a) urban structure
  aa) down-town area or outlying area
  ab) density of housing
  ac) density of employment

b) topography and climate
  topographic variations and climatic conditions

c) social status of passengers
  socio-economic status, car owning

d) traffic demand
  da) length of journey
  db) nature of traffic demand,
    commuter traffic or shopping traffic

e) services provided
  - ea) mode of transport (travel speed, cf. above)
  - eb) route pattern (radial or tangential)
  - ec) convenience of access and attractiveness of footways and stations
  - ed) frequency of service, punctuality, regularity.

Walking distances are not only judged by the time aspect but to a high degree also by the aspect of inconvenience which includes physical effort, changing and unpleasant weather, effect of traffic noise, traffic dangers etc. Over and above a certain walking distance, the effort in terms of time and inconvenience seems, to the passenger, to be greater than it actually is.

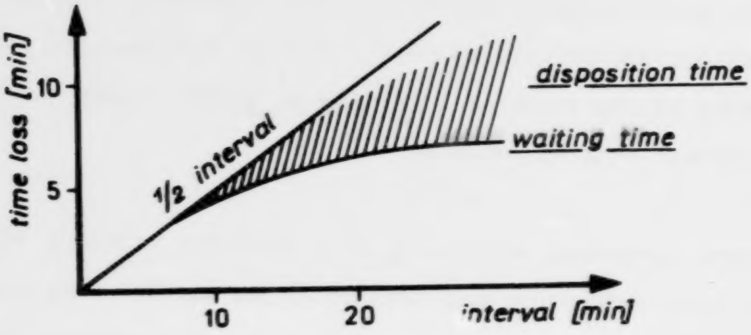
The conclusions drawn from an UITP inquiry [3] suggest as acceptable walking distances:

for tramway and bus services	300 to 600 m
for rapid transit systems	400 to 1000 m.

The lower values apply to the inner city areas whereas the higher values apply to the outer districts and suburbs. One way of keeping walking distances as short as possible for all public transport users is by increasing the density of building in the vicinity of stops and stations. While in areas with an even density of building the average walking distance for all users is about 70 % of the maximum walking distance, it can be reduced to about 50 % by increasing the density of building in the vicinity of stops and stations.

1.2.4 Frequency of Services

The average waiting time of passengers is determined either by the frequency of service if a system operates according to a periodic schedule, or by vehicle availability for demand-operated systems. Time losses not only result from the time spent waiting at the station, but also - for systems with long intervals between services - from the disposition time at home. Where systems operate at intervals of up to 6 minutes, users tend to come to the station at random, without sticking to a time-table (waiting time = 1/2 interval) because of the high frequency of services provided whereas for intervals above 10 minutes users stick to the time-tables and the average waiting time at the station is lowered to a limit value to which a time loss in terms of disposition time at home has to be added.



With demand operated systems there is no disposition time element at home.

Differences between the various systems exist also with regard to the waiting times at the stations: systems operating regular scheduled services produce their longest waiting times during off-peak and post-peak periods (when frequency of service is low) whereas demand systems produce their longest waiting times during peak hour traffic (when cabin occupancy and vehicle fleet usage are at their highest).

The demands for a higher frequency of scheduled services or a faster availability of demand-operated vehicles are primarily aimed at reducing waiting times.

1.2.5 Reliability (Punctuality, Regularity of Service)

In addition to the average waiting times, passengers give consideration to the fact as to what degree departure and arrival times are calculable with a certain measure of exactitude; predictability depends on the operating concept (demand system or no demand system), and on the likelihood of delays (sharing of the right-of-way, use of public roads, technical or weather-related causes).

Systems operating according to a periodic schedule should vary their departure and arrival times as little as possible within one day, within a week or a year; departure before scheduled time should be avoided at all costs; the frequency and extent of delays can be reduced to the following standards:

for systems separated from private traffic

only a max. of 3 % of all trips may be delayed by more than 3 min.

for systems sharing the right-of-way with private traffic

only a max. of 10 % of all trips may be delayed by more than 3 min.

1.2.6 Change of Destination During the Journey

This includes the desire to switch to a destination other than the originally planned one, and the desire to interrupt the journey at any time. It should also cover the possibility - as far as automated systems are concerned - to return to the point of origin before reaching the coded destination. With conventional systems, change of destination during the journey is provided for by fixed stops (or upon request), and the resulting possibilities of transfer or alighting.

Demand operated systems without operating personnel should always provide for trip interruption at any time; it would be desirable to design systems which enable passengers who want to change to another destination to continue their journey on the same vehicle without the requirement of transfer.

Optimum conditions for a change of destination during the journey are provided by taxis or the dial-a-ride bus as they do not have to serve fixed stopping points and information to the driver during the journey is sufficient to effect a change of destination.

1.2.7 Individuality, Privacy

The inadequacies of "mass" transit systems have led to the development of demand-operated "individual" small cabin systems; leaving aside the operation of small vehicle units, or a corresponding operating concept for large cabin systems (e.g. possibility of booking a cabin for exclusive use during one journey), a certain amount of individuality can also be achieved in large-capacity vehicles by the arrangement and design of the seats/grouping of seats.

With double-ended vehicles more individuality can be achieved by the arrangement of compartments than by longitudinal seat arrangement; with single-ended vehicles all seats should be arranged in transverse direction and in the direction of travel; a certain number of single seats should be provided. Annoyance of seated passengers by standing passengers should be avoided. For large cabin systems it may be desirable to provide for the possibility of seat reservation at a fare supplement.

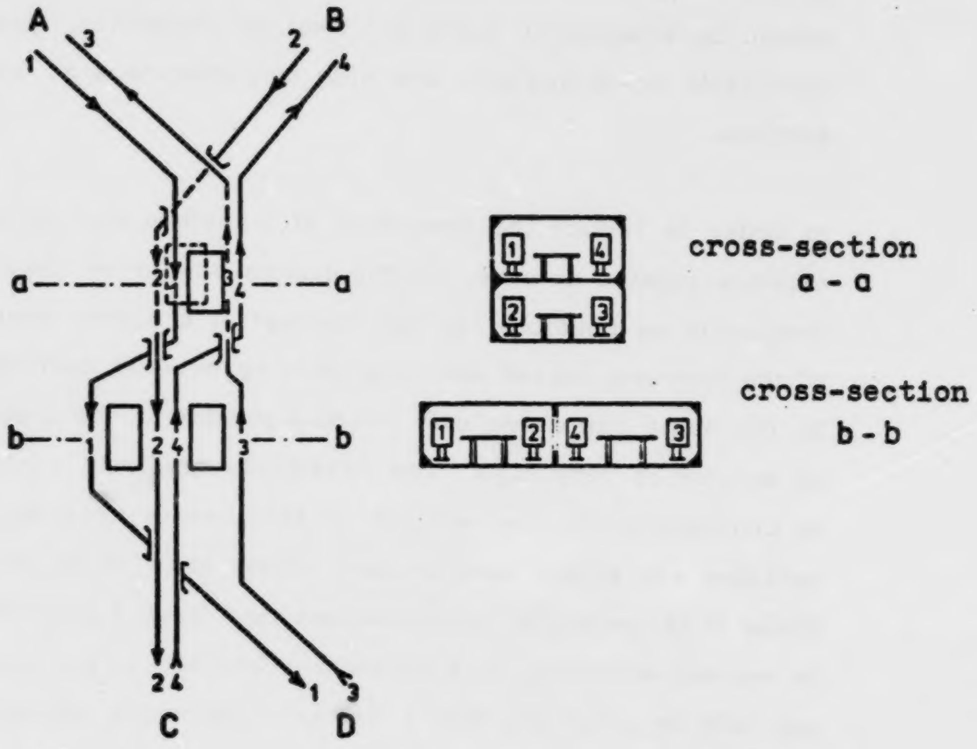
Studies have, however, indicated that the importance attached to individuality is less than is generally believed [4].

1.2.8 Direct Routing/Transfers

Transfer from one system to another is not only time-consuming but also inconvenient (e.g. interruption while reading, giving up a seat, physical effort, impairment through climate etc.). For all major transfer facilities cross-platform transfer patterns would be a desirable solution; at rapid transit junctions linking two lines at sharp angles, the possibility of transfer to another direction should be facilitated by designing two transfer stations in a tandem arrangement (one for traffic moving in the same direction, the other for traffic on the same line) (see also diagram); special importance should be attached to sufficient weather protection, good time-table co-ordination, and aids to pedestrians at transfer stations.

In order to reduce the frequency of transfers and consequently network-related detours, traffic routes should be linked as frequently as possible, in the interest of a higher density of the network; mixed services serving several destinations on the same route are only recommendable if the frequency of service is very high. The possibility of direct routing is provided where the network of services is very dense, vehicles are small, and no fixed routes have to be served. While it is generally recommended that fixed routes should be served according to a periodic schedule, direct routing can only be achieved with a demand-responsive operating concept.

Direct services as envisaged for the dual-mode operation are preferable to systems requiring feeder and distribution lines.


A
B
1
3
2
4
a
a
b
b
2
3
4
1
2
4
3
2
4
1
3
C
D
cross-section
a - a
1
4
2
3
cross-section
b - b
1
2
4
3

Track arrangement and cross-section of stations for optimum transfer conditions ("across-the-angle" transfer is transfer from A to B and from C to D)

1.2.9 Protection against Atmospheric Conditions

Location, size and design of stops or stations largely condition the nature of the protection against atmospheric effects.

Owing to their physical arrangement, underground stations afford protection against rain and snow and to some degree also against temperature and wind. The protection provided by elevated stations is only slightly better than that given by ground-level shelters. These are, however, often insufficient, especially for greater numbers of passengers, where there is no provision for adequate protection against variation of temperature, and in most cases no protection whatsoever against splashing. In order to improve the protection against rain and snow, splashing, extreme temperatures and wind, it would be desirable to design ground-level facilities as "closed" shelters; for all systems equipped with "closed" stations (such as underground railway stations) still better protection can be afforded by partitions between platform and track.

1.2.10 Information about Using the System

The physical and psychological demands on the passenger before and during the journey are reflected by the degree to which he becomes involved in the transportation process. One aspect is orientation and information; this applies mainly to strangers, people who are not accustomed to the system, or handicapped persons. The amount of orientation that is necessary for using the system increases with the rate of automation (handling done by the passengers) and the size of the facilities.

Efforts should be made to reduce the amount of information needed and to co-ordinate the information and handling systems in public transport (e. g. handling and operation of machines). For this purpose, the use of colours, pictograms etc. is recommended. In order to facilitate the use of the system, additional telephone or other information could be provided.

Passenger involvement in the operation of barriers, turnstiles, gates etc. should be kept to a minimum.

Transport systems can be assessed on the basis of the amount of

- orientation/information they require
  - at access (passageways leading to and from the facility)
  - on time-tables
  - fares
  - handling of machines
- action required
  - for ticket purchasing
  - for ticket collecting and cancellation
  - for leaving the exit or station facilities
  - in the event of break downs or emergencies.

1.2.11 Boarding and Alighting Conditions

For an assessment of the boarding and alighting conditions the following elements need to be considered:

- difference of level between platform (or carriageway) and the upper edge of the vehicle floor
- number and dimensions of doors
- design of door frames (provision of door barriers, holding bars, catch areas in the vehicle compartment, edging, door movement)
- door opening and closing mechanism.

For each line of passengers, the clear width of the door should be a multiple of 0.65 m. For large-capacity vehicles it is desirable that each door should be able to handle two lines of passengers. If standing passengers are carried, the height of a door should be $\geq$ 1.90 m. The number of passenger lines needed for boarding and alighting is determined by the number of seated and standing passengers per vehicle and by the maximum acceptable time for boarding and alighting. If the stopping time in the station is 20 sec., each passenger line would hold about 20 passengers (standing passengers are calculated at 0.25 m^2 per person).

Different heights and depths of steps should be avoided (risk of stumbling). The pitch (tread a: riser s) should wherever possible correspond to the convenience formula a-s = 12 cm.

For safety reasons, the distances between the edge of the platform and the centre of the vehicle door should not exceed the following measurements:

250 mm in curves
100 mm on a straight track.

Unintentional opening of the doors by passengers should be made impossible. Opening and closing of doors at stations should take place without or with only a minimum of passenger involvement e. g. by means of contacts. Systems where passengers are required to board and alight while the vehicle is slowly moving along the platform, without halting, must be considered inacceptable because they exclude certain classes of passengers (handicapped persons, old people, children) from using the system.

The most important criterion for the assessment of boarding and alighting conditions is, however, the difference of level between vehicle floor and the edge of the platform.

1. 2. 12 Driving Noise

In this context, driving noise is understood as the noise levels perceived inside the vehicles. Driving noise is transmitted directly as air-borne sound, or indirectly as impact noise to the passenger compartment where it affects the well-being of the passengers. The physical unit for the measurement of noise levels is dB (A).

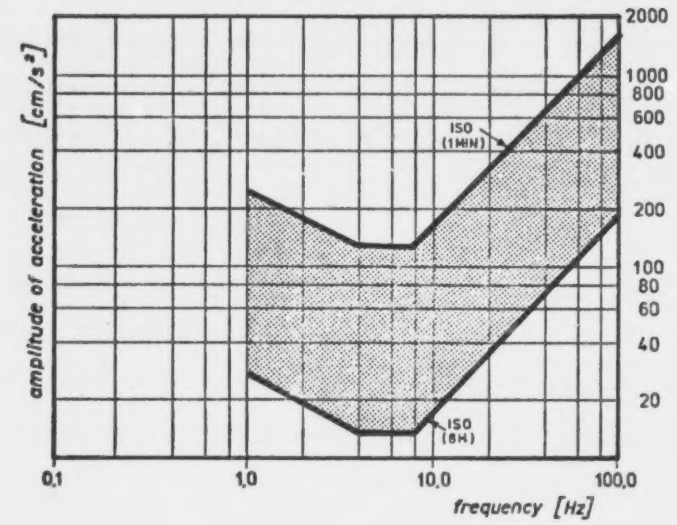
Maximum permissible noise values are determined by the requirement that noise levels in vehicles and therefore also the original driving noises should permit a conversation at normal voice level; for this to be possible the sound pressure of the voice must exceed the sound pressure of the vehicle noise by 10 dB.

In view of this requirement and the degree of nuisance caused by different levels of internal noise, efforts should be made to keep noise levels inside vehicles below 70 - 75 dB (A). This can be done by insulating passenger compartments against air-borne sound and impact noise from outside and by modifying noise intensive vehicle parts.

1.2.13 Smoothness of Vehicle Operation

Smoothness of operation is a function of the dynamic running of a vehicle; it is affected by unevenness or inadequate positioning of the track, as well as by other external disturbance forces, such as wind. Human perception of vibration is related, among other things, to the exciter frequency and to the intensity and direction of accelerations (perception of horizontal and vertical vibrations is different).

The below ISO values for the upper limits of vehicle vibrations (in terms of passenger convenience) can be considered as internationally acceptable standards [5].



The important criterion, however, by which the smoothness of transport systems is assessed is the nature of the guideway, in particular the positioning accuracy and its elasticity. But also certain technical factors of vehicle design have to be taken into consideration (i. e. nature of the cushioning system which is determined by the empty/loaded weight ratio).

An inquiry among public transport users conducted in the FRG [6] showed that out of 5 negative points, the various modes of rail-bound traffic were given between 1.66 and 2.89 points, whereas bus services received 3.72 points.

1.2.14 Air Conditioning (Heating and Ventilation)

The air conditioning of urban and short-distance transport systems is in need of improvement. One desirable improvement is the adaptation of air conditioning in vehicles to the rate of occupancy and to the external temperature. The quality of air conditioning is determined by the technical equipment but also by the frequency of stops, the dimensions of the doors and the duration of door opening. The important factors are:

- dry-bulb temperature)
) effective
- wet-bulb temperature)
) temperature
- wind speed)
- heat radiation
- cleanness of the air
- odorous substances.

Furthermore it would be desirable to improve the heating arrangements prevailing in nearly all transport systems which are only thermostatically controlled, if at all. A rapidly effective cooling or heating cannot be achieved by small window hatches or by simply using the heat output of the brake rheostats.

For longer journeys the internal air-conditioning of vehicles should be related to passenger comfort standards, in atmospheric terms; for short trips, it is important that there is no major difference between the effective temperature inside the vehicle and the external temperature. It should be possible to provide for fresh air supply without the introduction of noxious or harmful odorous substances.

Air conditioning and its related difficulties have to be seen in the context of the operating concept (frequency of passenger exchange) and the type of stops or stations (open or closed).

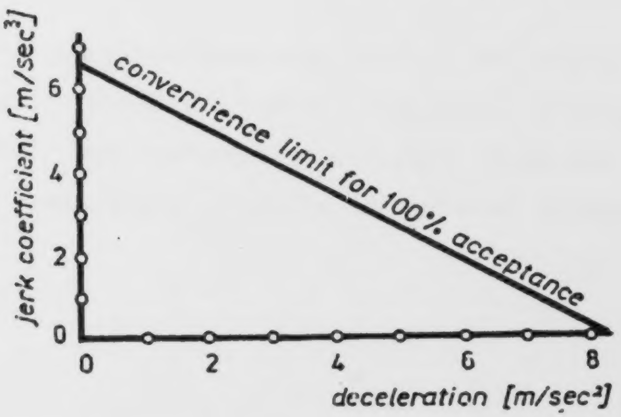
1.2.15 Acceleration, Deceleration and Jerk

Acceleration, deceleration and jerk are caused by the following factors:

- change of speed
- curves
- relative motions of passengers in the vehicle while it is negotiating a curve (Coriolis acceleration)

When changing from a steady to an unsteady motion, the resulting jerk values largely determine the maximum admissible values for acceleration and riding comfort. Where higher jerk values are accepted, acceleration values should be lower and vice versa.

The following relationship applies to seated passengers:



The below values are suggested as guide-lines which transport systems should attempt to comply with:

for standing and freely moving passengers

longitudinal and lateral jerks = 1,5 m/s^3
longitudinal and radial acceleration = 2,5 m/s^2
emergency braking deceleration = 4 m/s^2
Coriolis acceleration = 0,3 m/s^2
vertical acceleration = 1,2 m/s^2
(at a pedestrian speed of 0.8 m/s)

for seated passengers

longitudinal and lateral jerk = 2.5 m/s^3
longitudinal and radial acceleration = 5 m/s^2
emergency braking deceleration = 8 m/s^2
vertical acceleration = 1.2 m/s^2

Acceleration and deceleration values are only inaccurate judgment criteria (regardless of the type of right-of-way used). Jerk values, however, are a more differentiated instrument of assessment. The various elements to be taken into consideration are: jerk limit values at take-off and when the brakes are applied, frequency of jerks and their magnitude when the vehicle negotiates a curve, at change of vehicle inclination, and with the vehicle on a straight track.

1.2.16 Harassment, Criminal Acts, Vandalism

Growing automation of the operating and handling techniques has resulted in an increase in

- passenger harassment
- vandalism, and
- criminal acts

This aspect is given much consideration in connection with the planned introduction of fully automated systems.

Measures for the protection of passengers are necessary on all systems operating largely without train and station personnel: such as duplex telephones on vehicles and stations as well as television monitoring with the possibility of intervention from the operations centre.

Several rapid transit operators are now facing the decision whether to push forward the automation of their systems or to safeguard a higher degree of passenger security by slowing down the automation process and by maintaining their operating personnel. Television cameras surveying platforms, access and transfer tunnels of underground stations cannot provide the same degree of safety and security as surveillance personnel. However, police agents escorting underground trains would not be an acceptable alternative either. In any case it will be necessary to examine whether the amount of maintenance, repair and servicing required by surveillance equipment and the additional surveillance personnel are not likely to offset the personnel savings hoped for by the introduction of automated operation.

1.2.17 Transportation of Luggage

The requirement that a transport system should provide for the transportation of luggage applies to both vehicles and stations.

Public transport users want to be able to carry along their luggage, both in the vehicles, and in access and transfer facilities, as well as temporarily depositing it at the station.

In large cabins (from 6 seats upwards) and high-capacity vehicles (more than 30 seats) space for the stowage of bulky objects, (i. e. wheel chairs, prams, skis) can be made available (at the expense of seating capacity). Problems arise, however, in the event of high traffic demand. Carriage of luggage should not cause a problem not even with small cabins.

Where small cabins offer sufficient space for bulky luggage, this space can also be used by standing passengers - at least by children -. But then their capacity of operating with high acceleration and deceleration values is reduced as these are only acceptable for seated passengers.

In vehicles, the provision of sufficient space for small luggage such as luggage racks, would be desirable. Stations should be equipped with lockers as a special service for passengers wishing to temporarily deposit their bags. Furthermore, they should provide transportation aids like people movers, escalators, lifts etc. for the benefit of handicapped persons, mothers with prams etc.

1.2.18 Consideration of Special Classes of Passengers

Special classes of passengers could be:

- children under 15
- older people above 65
- handicapped persons

- passengers carrying loads, pushing prams or in wheel chairs
- foreigners
- strangers.

Studies conducted in the Hamburg area indicate that one out of every four passengers belongs to one of the above categories. The requirements of these particular passengers are as follows:

Stops and stations

- short walking distances from door to station and within stations;
- level differences being kept to a minimum;
- pedestrian aids for overcoming differences in level;
- clear arrangement of the stations;
- provision for special services (shops, telephone booths, city maps, toilets etc.);
- comfort (seat availability);

Information

- simplicity and intelligibility;
- guidance by means of colours and pictograms;
- foreign language information;
- information columns;

Ticket purchasing

- simple fare structure;
- simple handling of machines;
- acceptance of bank-notes;
- return of change;

Passenger handling

- automatic doors;
- non-requirement of passenger participation in vehicle dispatch and destination coding;

Vehicles

- seat availability;
- space for loads, prams and wheel chairs;
- no steps;
- wide doors;
- view of outside environment;
- jerk-free riding.

As some of the requirements of individual groups of users might conflict with those of others, it will be necessary to individually weight them in order to arrive at an overall appreciation of the requirements of all special classes of passengers. The needs of these users must be given special consideration, especially when developing new transport systems.

1.3 Requirements and Judgment Criteria from the Point of View of Town and Traffic Planning

From the point of view of town and traffic planning, the standards which a transport system is required to meet are determined by the interaction of traffic and land development structure. Special interest is devoted by the various parties concerned to the quality of development generated by traffic projects, to their assimilation with the urban construction pattern, and to their possible impact on the modal split. Regard must also be paid to the effects of a transport system on the establishment of a regional master plan for traffic and transport planning (Generalverkehrsplan) (space-time-relationsships, modal-split) or on land use plans (effects on density of building and land use/route reservation for a transport system).

For the purpose of town and traffic planners it is important to distinguish between requirements on the one hand and judgment criteria on the other. There are, for instance, some requirements of transport systems which cannot be used for the purposes of an inter-modal evaluation. This applies for example to the capacity of a transport system. Capacity is a prerequisite for a system's capability to cope with a given volume of traffic, it is, therefore, a selection criterion for a given application, but no criterion for system evaluation.

1.3.1 The Form of the Services Provided

The form of public short-distance transport services develop as a function of the prevailing zoning structures, depending on density of building and aera size. Different forms of services have developed owing to a demand for higher traveling speeds for greater distances or for more demand-responsive traffic in areas with low passenger density.

The nature of the services provided can be broken down into the following sub-elements:

Type of routes operated

- fixed routes with fixed stops;
- flexible routes in combination with fixed or freely selected stops;

Frequency of service

- scheduled services (time-table);
- demand-operated services;

Modal division of transport functions

- one-mode service (services are provided by one transport system only);
- multi-mode service, (division of transport services among several modes, for instance, in the framework of an integrated overall network);

Speed of Service

- fast means (systems) of transport;
- slow means (systems) of transport;
  (e.g. road systems)

Type of passenger transportation

- collective,
- individual;

Type of motion

- with stops,
- continuous movement without stops (e.g. people movers).

The type of service provided is a combination of the above-listed elements some of which effect certain others. For example, fast and collective transportation in large conurbations is (usually) performed by a system operating scheduled services (time-table) on fixed routes in a multi-mode integrated network.

Public transport in high-density areas is generally characterized by decreasing density of traffic services with increasing distance from the city centre - in terms of density of routes and stops and frequency of services. This is due to the mostly radial structure of the route networks in peripheral areas and the habit of "advancing" terminals (turnaround points). The loss of service availability in terms of time and space cannot be compensated for by the provision of cross-routes (tangential lines). To some extent, however, these structure-related shortcomings can be removed by cooperation and coordination between public transport and taxi operators, for example, by establishing scheduled taxi services [9].

The requirements to be fulfilled by transport systems with respect to the form of the services to be provided are as follows:

- systems should be able to provide a wide variety of services in order to satisfy as many demands as possible and thus to reduce the number of necessary transfers in large conurbations;
- the number of individual transport systems within an intermodal service system should be kept at a minimum;
- the systems should be capable of being fully integrated in an intermodal operating and fare system;
- short-distance transport systems should be operated on their own lanes or right-of-way (separation of traffic) while aiming at an overall optimum use of the available land.

1.3.2 Development Effect

Distances between stops and stations, the density and the type of network operated determine the quality of development arising from a transport system. Any evaluation of rapid transit systems must also include its feeder lines, as the service area of a rapid transit station is not limited to its immediate neighbourhood within walking distance but also extends to the areas served by the feeder lines.

However, for high-speed and high-capacity short distance transport systems it is desirable to provide a density of network which minimises travel times on the slower feeder services. In inner city areas additional or supplementary feeder or distributor services for rapid transit services can be generally dispensed with.

In the interest of a good development, special consideration must be given to the provision of adequate tangential services in the network.

The distance between two stops or stations should not exceed the double length of the maximum acceptable walking distance between home and station, - depending, of course, on the type of system used. The upper limit for maximum acceptable walking distances is about 1000 m = 15 minutes.

The development effect of elevated or underground systems can be enhanced by the layout of the access, i. e. their design should avoid dangerous road crossing by passengers, and provide weather protection over part of the access.

1. 3. 3 Capacity

A distinction has to be made between theoretical and practical capacity. For some transport systems there is a considerable discrepancy between their theoretical and the practical capacities.

A further differentiation must be made between route and station capacity.
Route capacity is determined by:

- the operating concept (on- or off-line operation);
- distance between stops/stations for on-line operation;
- duration of stop (with on-line operation)

- operating speed;
- acceleration and deceleration values
- headway control/safety system (e.g. relative and absolute braking distance);
- obstructions during the journey (slow-down sections, traffic signals, private traffic etc.);
- vehicle capacity;
- method of switching (switch time, if appropriate)

The capacity of a stop or station is conditioned by:

- line capacity;
- number of stops on one or several tracks or traffic lanes;
- on-line or off-line operation;
- handling system;
- acceleration and deceleration values, headways etc.;
- headway control system.

At stops with high traffic generation (e.g. near activity centres attracting large crowds) the system must be able to provide maximum line capacity.

When determining the design capacity of a system, attention must be paid to the accuracy of the projected data, to the absolute forecasted values and to the time of the forecast. It is recommended that provision be made for reserve capacity.

1.3.4 Physical Integration into the Urban Pattern

Systems operating on a separate right-of-way at surface-level cause considerable problems of integration into and assimilation with the urban pattern partly also for aesthetic considerations.

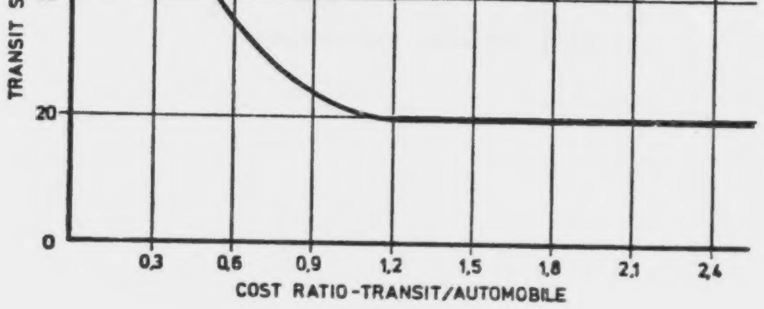
This aspect is of particular importance where old, historic towns are concerned. Therefore, under-ground operation is in many cases inevitable, although this alternative may also give rise to physical problems of integration (e. g. by-passing of building foundations, relocation of supply lines and cables etc.). Elevated guideway systems often follow the routing of public roads, wherever possible their guideway alignment should be adapted to the geometric characteristics of these roads. Where road transport systems are used, it may be possible to reserve certain roads exclusively for public transport. This solution is preferable to elevated systems with their problems of physical integration.

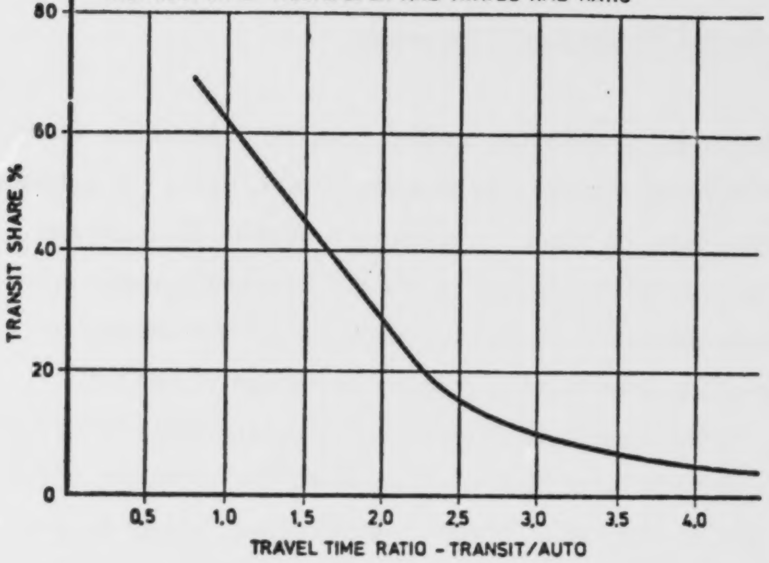
Other very important criteria of physical integration are the geometric characteristics of a route, such as minimum curve radius (at limited and at design speed), for the flexibility of the routing; as well as maximum inclination, in the interest of short ramps at overpasses or underpasses.

Another criterion of assessment is the total cross-section of a system - i. e. the cross-section of its guideway plus clearance gauge of the vehicle. In this connection it is of primary importance whether the system or what proportions of it are underground, at ground-level, or elevated, and how many of the stops or stations - depending on the operating concept - have to be on-line or off-line. Stations also have to be assessed under the aspect of physical integration and space requirements (cross-section and length of surface needed).

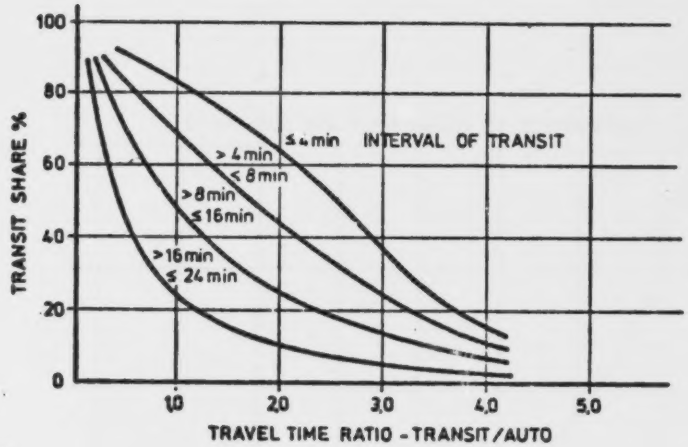
1.3.5 Effect on Public Transport Patronage

The improvement of existing public transport systems and the use of new-type means of transport are likely to enhance the attractiveness of public transport and thus to increase its share in the total amount of traffic carried (modal split). Such improvements could for instance be in the nature of higher traveling speeds and greater passenger comfort. Moreover, measures which improve the availability of public transport services are likely to increase the mobility of the traveling public. To what extent technological changes can effect a major shift in the modal split in favour of public transport is still unknown. Existing modal split models are predominantly based on travel time and cost comparisons as the main influencing factors. The following diagrams illustrate the modal split situation as it results from a Canadian study for the Toronto area [2].





A German study [7] includes frequency of service as an additional parameter to the travel time ratio.



Further parameters, in addition to travel time and travel cost are:

- travel service,
- income class of users,
- purpose of travel,
- direction of travel (radial or tangential routes),
- travel distance,
- car ownership,
- availability of parking facilities at destination.

In the interest of greater accuracy it is recommended to use multiparameter models.

It may be taken as a fact that the modal split is more strongly influenced by political decisions than by any kind of improvements aiming at a greater attractiveness of public transport. Such political measures can be in the nature of: changes in the level of public transport fares, parking limitations, general increases in the cost of private car usage. Administrative efforts by city and traffic planners to encourage wider usage of public transport, especially during off-peak periods, should be assisted by measures enhancing the attractiveness of public transport.

Even so, a major change in the present pattern of private car usage seems very unlikely to come about, for the following reasons:

- ownership mentality,
- status symbol,

- feeling of personal responsibility for maintenance and servicing of one's own car,
- adaptation of car model, colour and equipment to individual taste,
- serviceableness for other purposes apart from urban trips,
- individual influence on departure time, traveling speed and route.

1.3.6 Design of Transfer Facilities

The desirable standards for the design of transfer facilities and the attractiveness of transfers largely depend on the type of transport system concerned. The degree of physical integration depends on the prevailing urban structure, whereas the requirement of minimum constructional outlay for handling facilities is subject to the nature of the transfer facility (interchange of two routes of the same mode or of different modes - integrated or not in an intermodal operating and fare system).

The amount of construction outlay for a transfer facility should be primarily determined by passenger interests. Some of their basic requirements are: short walking distances, good protection against environmental influences, few level differences, and installation of pedestrian aids.

1.3.7 Disruption of Traffic during the Construction Period

The amount of disruption caused by the construction of new transport systems is sufficiently demonstrated in a number of cities engaged in building rapid transit systems.

In the interest of neighbourhoods and other transport users, the inconvenience and obstructions caused by the construction of transport systems should be minimised wherever possible. In order to allow for shorter term adaptations to changes and new developments (e.g. in the zoning structure), the amount of construction and therefore also construction time should be reduced.

Open-cut construction is time-consuming and causes considerable disruption of traffic and other inconveniences. Therefore cut-and-cover construction or shield tunnelling (even at higher costs) are preferable. The negative effects connected with the construction of elevated systems are of shorter duration and therefore cause less inconvenience for the public. In order to further reduce construction periods and related nuisance, modular construction should be encouraged wherever possible.

1.3.8 Influence on the Urban Form

In view of the high investment outlays involved in the construction of rapid transit rail systems as well as other track-bound systems it is absolutely necessary to demand a coordination between traffic and urban planning. Where urban rail systems are already in existence, their traffic value should be enhanced by additional urban planning measures. Rising land prices as a result of a new rapid transit line often produce by themselves the desired effect, i.e. more intensive land use (higher density of development) in the immediate vicinity. In order to achieve an optimum economic and traffic development in the outlying areas of large conurbations and to encourage their development through rapid transit lines, city planners must design development axes along which a high density of development can take place.

By way of illustration, the effects on the prevailing development structure following the completion of the first Canadian underground system [8] are listed below:

- the capital costs of the underground system of 67 million Dollars gave rise, within a relatively short period of time, to investments for urban and industrial development, in the order of 10, 000 million Dollars.
- two thirds of all increases in land price at Toronto, over the last ten years, are attributable to the construction of the underground system.
- two thirds of all new buildings that developed in the course of the last five years are within a five minute walking distance from the underground system.

Systems involving low infrastructure costs and a low capacity presuppose a homogeneous pattern of land use and also a largely homogeneous generation of traffic. All public transport systems (with the exception of taxis and demand operated buses) depend on a dense development providing the passenger volumes necessary to match their respective capacities.

With fixed stop systems, zoning and development are determined by the passengers' demand for short walking distances i.e. density of development and consequently the number of passengers captured should decrease with growing distance from the stops (cf. Chapter 1.2).

1.4 Requirements and Judgment Criteria from the Point of View of Community/Environment

The introduction of a new transport system will not only have to enhance the attractiveness of public transport for its users; it should, at the same time generally improve the living conditions of all people living in the area served by it. These include all users of public and other modes of transport, as well as all those living in the immediate vicinity of main roads, public transport systems or near their operational facilities (depots etc.). In other words, this applies to all persons including those affected to a greater or lesser degree and at various times by the exhaust gases and noises produced by public transport systems.

Some of the requirements and judgment criteria dealt with under this heading will overlap with those of other interested groups. For instance, surface requirement is also an important criterion for town and traffic planners, as safety is important to the operator.

The requirements referred to hereafter, concern the public in general. Therefore, they could also be considered as political aspects. As the funds needed for transport investments are, in the last resort, paid for by the general public, it will also be necessary to take capital costs into consideration.

1.4.1 Safety

Safety relates to

- safety of access to and from stops and/or stations
- safety at stops and stations and on the platforms (also during boarding and alighting, during vehicle arrival and vehicle departure);
- during the journey.

The general public is not only interested in passenger safety while using the system, but also in the costs resulting from material damages, personal injuries and fatal accidents as they constitute a burden for the general economy (overall economic interest). Therefore, this paragraph will take into account accidents between public transport systems and other modes of transport, passenger accidents as well as operating personnel accidents.

A statistical record in the Federal Republic of Germany for 1970 shows the following relationship between fatal accidents (death up to 30 days after accident) and passenger-kms carried, both for public and private transport:

bus transport	1 death per 1000 million passenger-kms
rail transport	3 deaths per 1000 million passenger-kms
passenger car	22 deaths per 1000 million passenger-kms

These figures include short and long-distance traffic and indicate the trend, i.e. low safety for private transport. The figures for rail transport cover routes with separate track as well as those without separate track.

For the purposes of this study it is, however, necessary to isolate the figures of accident frequency (sub-divided into deaths, heavy and light injuries, material damage) for short-distance transport, and within short-distance transport to make a sub-division: buses, tramways and rapid transit railway systems. They can then be used as an indicator of system safety.

The following mean values of system safety for 1969/1970 were taken from a dissertation on accident frequency in 8 major cities in the Federal Republic of Germany [18]:

buses and tramways	3.35 accidents per 1 million passenger-km
rapid rail transit	0.82 accidents per 1 million passenger-km

Although tramways include a proportion of separate and protected tracks, the above comparison clearly demonstrates the difference between systems which share the right-of-way with private transport and those running on separate tracks. Moreover, the figures for rapid transit rail systems also include suicides which cannot be attributed to the system, thus widening the gap between the two types of transport systems in respect of their safety performance still further.

Depending on the cost valuations applied to the different types of accidents (deaths, heavy and light injuries and material damages), it becomes evident that the accident costs attributable to rapid transit rail systems amount to no more than 8.5 - 16 % of the accident costs caused by buses and tramways.

Regarding the accident safety of automated rail systems operating without driving and train personnel, one has to bear in mind that on the one hand these systems run on a separate, protected track (such as rapid transit systems) while on the other hand, there might be a certain proportion of accidents which could be avoided by the intervention of operating personnel. Hence the requirement that safety systems have to be developed for automatically operated systems without driving personnel which garantee at least the same level of safety as conventional rapid transit systems. There is an advantage in automating certain elements of operation, thus relieving the personnel of repetitive and tiring functions or introducing improvements which exceed human capacity (e. g. shorter braking distances through ATO).

1. 4. 2 Energy Sources

The public takes an interest in the energy consumption characteristics of transport systems because of their impact on energy availability and environment. This aspect will also be considered as a cost item from the operator's point of view in Chapter 1. 5. 7.

Type and level of the energy consumed and its impact on energy availability and environmental damages are determined by the following factors (cf. Chapter 1. 4. 3):

- transport vehicles (size, cross-section, weight and length of vehicle);
- method of propulsion (suitable for all or only a few energy sources);
- system of energy conversion (efficiency of on-board or central conversion of primary energy);

- support and guidance technique (frictional resistances of wheel-supported and guided systems; power consumption of contactless support and guidance systems);
- vehicle utilisation (load factors, relationship of empty kms versus useful kms);
- transit speed (distances between stops, acceleration and deceleration abilities, max. speeds etc.);
- right-of-way (separate or sharing with private transport; favourable routing).

Another important aspect in the context of power consumption is a system's capability of recovering a certain amount of the energy consumed by regenerative braking, or of storing the braking energy in energy stores.

Further energy saving possibilities are:

- train formation by coupling together of vehicles;
- difference between route distance (from point of departure to point of arrival) versus bee-line distance;
- elevated separate rights-of-way (optimum conditions are provided by "humping stations");
- reduction of the number of intermediate stops (in extreme cases, no intermediate stops at all, like direct-routing concept of small cabin systems).

Energy consumption of private transport and its consequences are sufficiently well known through publications dealing with this subject. Therefore, the general public should be interested in the introduction of measures to reduce the use of private transport for certain purposes of travel (e.g. commuter traffic) in favour of public transport showing a lower specific energy consumption.

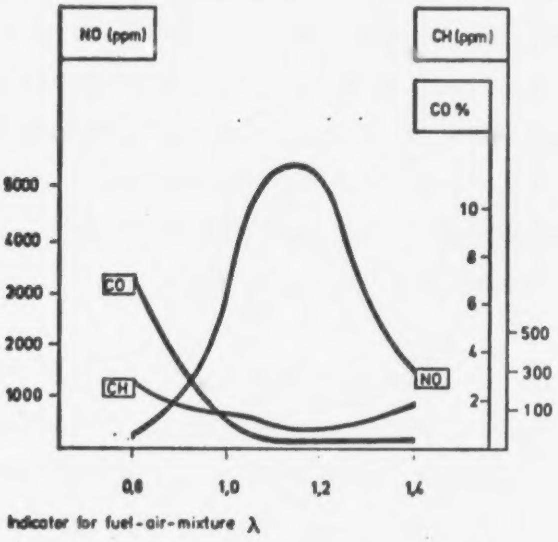
1.4.3 Emission of Polluting Substances

This paragraph deals with the emission of polluting substances and the resulting nuisance, i.e. pollution of the air by smoke, soot, dust, gases, areosols, steam etc. as well as by odorous substances. Most of these polluting substances develop as a result of the combustion process of the energy conversion, others are released through tyre wear, wear of the brake linings, carriageway or track etc.

A reduction of pollution should be possible without substantially increasing power consumption. Transport output in terms of passenger-kms should be the criterion for maximum permissible emissions; in other words, a heavy vehicle should not be allowed to have higher emissions than a light vehicle.

As the factors influencing type and level of energy consumption have already been discussed in the previous Chapter, only some additional factors are mentioned for consideration: The nature and the operational condition of the energy conversion system determine the composition and quantities of the polluting substances in the exhaust gases. Even a low polluting combustion with an economical system of exhaust gas purification at the power station is preferable to vehicle-mounted combustion engines subjected to varying operating conditions.

As yet there are no precise data on the toxicity of the various exhaust gas components and their harmfulness for the human organism, therefore, an objective assessment on their respective importances is not possible. However, if the combustion process of the Otto engine is improved, CO-emission is reduced, but at the same time NO-emissions, and later also CH emission levels rise.



It would be of great advantage if public transport systems were propelled electrically, if obstructions and intermediate stops during the journey could be kept at a minimum and surface frictions were low. Non-polluting conversion and storage of kinetic energy in batteries or fly wheel stores would be desirable. An assessment of pollution characteristics can be based on the following criteria:

- method of propulsion,
- size of vehicles,
- right-of-way (proportion of separate track or track-sharing with private transport),
- support and guidance system (with or without wheels).

1.4.4 Noise Levels

The relevant factor determining the nuisance caused by noise is the noise level felt in the vicinity. It is a function of

- the external noise levels produced by transport systems;
- level of the right-of-way (underground, surface level or elevated);
- distance from the source of noise;
- protective measures (sound screens and other devices);
- time of day, atmospheric conditions etc.

Another factor influencing the noise levels of a transport system, apart from vehicle noise, is the nature of the guideway (e.g. elevated guideways for suspensions systems) and its noise emission characteristics.

The following factors determine the noise emission characteristic of a transport system:

- propulsion and power transmission
- support and guidance technique
- traveling speed
- cushioning characteristics (track, vehicle etc.).

As the noises of road vehicles vary greatly in level and with time, their internal noise characteristics can only be assessed on the basis of the energy equivalent continuous sound level substituting an even and continuous sound for the individual sounds. There are recommended standards for permissible noise levels of road vehicles established by the European Community and the UN-Economic Commission for Europe [20].

	France	Denmark	Netherlands	Switzerland	Great Britain	Federal Rep. of Germany	ECE recommendations	EEC
	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)
	1962	1969	1966	1969	1970	1966		
Heavy motor vehicles, tractors and industrial vehicles	90	89 - 92	88 - 92	85	89	89 (92)	89 - 92	89 (91)
light goods vehicles	83	85	83	--	83	85	85	84
passenger cars	83	84	83	78 82 (Diesel)	84	80 (84)	84	82
motor cycles	86	82 - 86	83	82	86	84	82-86	--
mopeds and light motor cycles	76-80	82	73	70-73	77-82	73 or 79, respectively	82	--

Similar recommended standards should also be set up for public transport systems.

The nature of the guideway (underground, surface level or elevated) and the necessary noise protection measures must be related to the environment in which a system operates. The noise levels produced by elevated systems are generally higher than those of ground level systems, owing to the resonance of the structures.

The noise level standards applying to purely residential areas will be quite different from those which industrial zones are required to meet. In order to ensure that the planning standards for noise levels perceived inside houses (of, for instance, 45 - 50 dB (A) during daytime, and 35 dB (A) during nighttime) are not exceeded, appropriate measures will have to be taken in purely residential areas, such as adequate distance between right-of-way and building front, special sound screens, or even underground construction of the track.

The following criteria may be applied for an assessment:

- proportions of the right-of-way built underground, at surface level or elevated;
- method of propulsion (electric or combustion engine)
- maximum speed (graded: <40; 40-60; >60 km)
- support and guidance technique (solid rubber, patterned rubber, steel wheels).

1.4.5 Space and Surface Requirements

The physical installations of a transport system precludes the use of the required space and surfaces for other purposes. The amount of space and surface thus excluded for other uses largely depends on the physical layout of the installations concerned, i.e. surface level, elevated or underground construction.

Underground and elevated systems use comparatively little space and ground at surface-level (for access and exit facilities, structural supports). With underground construction, only the space of the tunnel profile is excluded from other use whereas surface level installations may have additional space and surface requirements apart from those imposed by vehicle gauge and clearances, which totally or partly exclude other uses (e.g. for safety reasons or reasons related to housing development - aesthetic reasons).

Systems using the space of public roads have the advantage that their traffic space and surfaces can be used by other transport as well. The disadvantages of private transport result from its parking space requirements at place of origin (home) and destination (work) of travel, whereas public systems need only one major installation (depot).

Elevated systems which operate one direction of traffic by means of rail mounted vehicles, the other by suspended vehicles avoid the problems connected with switch-point passing; they dispense with expensive over- and underpasses and thus reduce their space requirements. On the other hand, these systems suffer from the disadvantage that their networks are loop-shaped and that at terminals, rail mounted vehicles cannot be changed into suspended position and vice versa. The importance of these disadvantages depends on the topography and the zoning structure of the towns and cities concerned.

Speedy vehicle dispatch and short intervals between vehicles as well as the operation of small vehicle units are factors which help to keep the space and surface requirements of stops and stations low, compared with systems operating at relatively low frequency. Off-line stations are only justified where they warrant direct routing or a higher capacity of service.

1.4.6 Capital Requirements

The capital requirements of a system are determined by its system-related needs for:

- physical installations (tracks, stops, stations, buildings);
- vehicles, (passenger vehicles, maintenance vehicles).

An important factor determining the amount of capital needed is the track (underground, elevated or at surface-level). The cost per track-km also gives an indication of how quickly a transport system can be constructed and made available to the public.

Vehicle costs can be compared only on the basis of passenger carrying capacity (for seated and standing passengers). There is no correlation between vehicle size and cost per passenger carried. Higher purchase costs per passenger carried, for same capacity (e.g. railways versus buses), need not necessarily constitute a negative factor, as the life-time of vehicles is another important aspect to be included in economic considerations of that nature (as under 1.5.7). A compensatory relationship may exist between capital costs for vehicles and right-of-way. For instance, for a system operating a large number of small cabins, vehicle costs can be reduced by installing power supply and propulsion elements in the track (e.g. Poma 2000).

An assessment of capital requirements per km (including installations and vehicles) must be related to system and service capacities.

Systems with low capital requirements are only preferable to other systems if they also meet the following criteria:

- low operating costs
- long life time of infrastructure and vehicles
- low costs in terms of total impact on the community over time, including quantifiable and non-quantifiable effects.

Also the following secondary conditions should be met wherever possible:

- good physical integration into the prevailing urban structure;
- separation of the various transport systems;
- sufficient capacity and flexibility;
- low pollution and noise levels.

1.4.7 Suitability for Goods Transport

In theory, it is conceivable that a public passenger transport system operated on short distances is also used for goods transportation. The NATO-CCMS study on URBAN GOODS MOVEMENT (UGM) of April 1975 makes the following proposals:

- to introduce as a short-term solution (possible within less than a year) dial-a-truck services, similar to the dial-a-ride systems developed for passenger traffic;

- to introduce, as a long-term solution, new systems which are suitable for passenger and goods transport (e.g. rapid transit systems with exchangeable passenger and freight cars). The introduction of these systems would take a minimum of 3 to 5 years, in some cases as much as 10 - 20 years or more.

There is, however, a major obstacle against the usage of public short distance transport for goods carriage: goods have to be moved from - (consignor's)door-to(consignee's)-door, whereas passengers get to and from the station by their own means.

The carriage of goods on a public transport system usually comprises of three processes: transfer from the consignor's premises to the station, movement on the system, and transfer from the station of destination to the consignee's door. Thus, with the exception of roll-on/roll-off techniques, carriage of goods by public transport usually involves a break of load at either end of the journey on the public system. Moreover, further breaks of load are necessary for distribution onto different routes unless a system operates a direct-routing concept.

Goods handling, i. e. loading, transshipment and unloading require the availability of separate tracks and platforms aside from those serving passenger traffic. As any break of load involves the risk of loss or damage it would be desirable to operate goods haulage on a direct-routing concept.

A system used for goods haulage should also provide for the use of private sidings by those customers who receive or send large quantities of goods. An adequate supervision must protect loads against unauthorized interference while guaranteeing free access by the consignee.

In order to be able to carry a wide variety of goods such as furniture etc., the rolling stock should have a sufficiently large carrying capacity. Based on the capacities available in short-distance road haulage, it is recommended to use containers of the size 8ft x 8ft x 40 ft (244 x 244 x 1219 cm). This requirement is, however, incompatible with the dimensions of small cabins used in direct-routing traffic (less than 2 m wide).

In the UGM study freights are broken down into four weight-classes: 0 to 50 kgs; 50 - 150 kg; 150 - 400 kgs and >400 kgs. It further suggests that the main reasons for the uneconomic operation of goods transport are of an organisational nature.

For instance 1/2 to 1/3 of all small goods vehicles run empty, spend only 1/4 of their time on the road and serve the same routes, in part or total. Improvements of short-distance goods transport are possible in the following areas:

- reduction of freight costs and carriage time;
- reduction of traffic obstructions (congestions);
- reduction of noise, exhaust emissions and aesthetic impairments;
- energy saving;
- reduction of theft, loss and damage of goods;
- increase of traffic safety.

An assessment will have to take the following factors into account:

- operating concept (direct-routing, non direct-routing)
- type of stops or stations (on-line or off-line)
- vehicle size (small or large cabins, high-capacity vehicles).

1.5 Requirements and Judgment Criteria from the Point of View of Public Transport Operators

The principle responsibilities of a public transport operator comprise of all aspects of operation. Therefore, he is interested in all characteristics of a transport system which facilitate or complicate operation; naturally this includes all factors affecting operating costs.

A public transport operator is answerable to public authorities for the correct operational management of the transport system under his control. For instance, he has a statutory obligation to operate and to carry passengers, and accepts liability for the passengers carried on the system. But he can fulfill these obligations only if certain requirements are met with by the system.

1.5.1 Reliability, Safety and Security, Low Failure Rate

The degree of reliability of a transport system is determined by the likehood of system or component failures or break-downs (disruption of operation means disruption of service) over a given period of time. Break-downs may be caused by components faults, or tracks faults, or due to human error.

The break-down of elements or sub-elements may cause danger for persons and materials so that inadequate reliability of system elements (brakes) may reduce the safety performance of the entire transport system.

Component failures can be listed as follows:

- failures due to manufacturing faults or workmanship,
- failures caused by wear and tear,
- random failures.

A system's reliability is determined by the technical quality of its equipment, by the safety standards and the safety performance of its equipment (redundancy, fail-safe), by the level of preventive maintenance, and by the effects which other systems, other transport users, passengers and operating personnel have on its operation. The chances of errors of handling by users and operating personnel should be kept to a minimum.

Climatic conditions, affecting the reliability of system elements (e.g. failure of door mechanism caused by ice and snow), are more likely to lower the overall reliability of the entire system (e.g. by reducing the level of service or the punctuality of service).

A system that is prone to delays affects users and operators alike, i.e. operators must cope with changes in vehicle headways, and turn-round times by putting additional vehicles into operation or by other measures. As regards proneness to delay of public transport systems, (cf Chapter 1.3.5), the present performance of rapid transit rail systems can be adopted as a desirable standard.

In respect of elapsed time between two break-downs (meantime between faults), transport systems and their elements should come reasonably close to the standards set by rapid transit rail systems. Aside from the immediate safety of a transport system and its elements, the operator attaches great importance to such factors as how easily the effects of break-down in the system can be localized and how quickly they can be cleared. As a general rule, break-downs or failures in the system should not disrupt services for more than half an hour. Encroachment of break-downs on other parts of the system can be minimized through appropriate network design (i. e. provision of frequent linkage points in the network where vehicles can change over to another route; or operation of pure line-haul services, i. e. no overlapping of two or more services on a route or sections of a route; sufficient facilities for U-turns). Bus transport is less susceptible to service disruption as the break-down of one vehicle will not affect the services of following-on vehicles (possibility of by-passing).

The following factors should be considered when assessing a system's reliability:

- proportion of right-of-way shared with private transport,
- dependance on weather conditions,
- possibility of interference (or damage) by passengers and operating personnel,
- standard of technical safety (absolute braking distance, fail-safe, redundancy),
- effects of break-downs.

1. 5. 2 Vehicle Size

Vehicle capacity is determined by the type of service which a system is required to provide, by traffic demand and vehicle headways. Because of the need for sufficient operational flexibility (viz. following criterion), operators tend to favour vehicles with a high capacity and a seats/standing room ratio of about 1 : 1 (calculated on the basis of 0. 25 m^2/passenger).

Vehicle size is not a direct indicator of the capital requirements involved and vice versa. In terms of capital requirements (leaving aside such factors as track-guidance, life-time etc.), the cost per passenger room (standing room and seats) of small cabins may be lower or higher than of large-capacity vehicles. There is, on the other hand, an undeniable correlation between vehicle size and the necessary amount of maintenance and servicing: smaller vehicles need more maintenance and servicing than larger ones. For a given transport system, optimum vehicle size can therefore be determined on the basis of operating costs. In the framework of its research work, SNV [14] has recommended for rapid transit systems maximum train lengths consisting of three units as being best suited to adapt to changing demands. The smallest unit in this case would be a married pair of two vehicle units or an articulated train unit 30 - 70 m long, depending on traffic demand (and platform length).

1.5.3 Operational Flexibility

Operational flexibility means a system's capability to adapt to varying traffic demands. It covers two aspects:

a) a system's adaptability to short and medium term changes in demand (daily and weekly fluctuations of transport demand) which can be expressed as the relationship between minimum and maximum capacity and by its quickness of response to changing demand. Minimum capacity is determined by the number of seats provided by the smallest vehicle unit operating at minimum acceptable frequency. Maximum capacity is determined by the total number of seats and standing room available in conditions of longest possible train formation and maximum frequency of operation.

Comparing a 10-minute period at two different times of the day (off-peak and peak hours) the following situation results: See table on following page.

b) a system's adaptability to abnormal situations can be expressed by its stand-by capacity, i.e. of standing-room, and more specifically by its capability for various degrees of standing-room utilisation. Aspect a) above is based on a rate of standing-room usage of 0.25 m^2 per standing passenger, whereas in abnormal conditions standing-room may be reduced to 0.15 m^2 per passenger. While the need for adaptability as under a) is obtained to a higher degree with automated small cabin systems than with conventional high capacity vehicles, adaptability as shown under b) is

Vehicle Size

	Number of seats of smallest vehicle unit	Number of vehicles to operate as one unit	Number of seats and standees in smallest operating unit	max. number of journeys within a 10-minute period	Number of seats and standees of largest vehicle unit at maximum train frequency in 10-minute period	Adaptability
	1	2	3	4	5 (=2x3x4)	6 (=1:5)
Bus (VÖV-standard bus)	44	(1)	71	10	710	1 : 16
Rapid transit railway (Underground railway Munich)	98	3	290	6, 5	5655	1 : 58
Large cabin system (H-Bahn)	12	6	24	10	1440	1 : 120
Small cabin system (Cabintaxi)	3	(1)	3	150	450	1 : 150

greater with high-capacity vehicles owing to their higher standing room capacity. In abnormal conditions, rapid transit railways can handle 40 - 50 % more traffic than their maximum carrying capacity calculated on the basis of the normally acceptable rate of standing room usage (0.25 m^2).

1.5.4 Flexibility of the Infrastructure

Transport systems are more attractive for operators, traffic planners and also for the general public if they allow for easy, rapid and low-cost extensions and changes of their networks. Ideally, the requirement for adaptability to changes in demand permits route changes, line extensions etc., in other words it provides for constructional flexibility without major expenses. This is only possible with bus services while street car and rapid transit rail systems are much less adaptable. It is virtually impossible to pull down and rebuild tunnel constructions or to change elevated systems, and in planning such systems, full consideration should be given to the possible need to extend routes to meet future demands.

The following factors may be used for an assessment:

- proportions of underground, ground-level and elevated construction;
- cost per track-kilometer of underground, ground level and elevated right-of-way;
- extensibility of network (need to provide loops for turn-around at the terminal station; loop-shaped networks).

1.5.5 Personnel Requirements

All transport systems need personnel for their

- traffic departments (operational department)
- technical departments, and
- administrative departments.

In view of the difficulties that the operators experience - especially in highly industrialised countries - to get reliable and steadfast personnel for their traffic departments, (for a number of reasons, such as changing shifts, split-up shifts, night shifts, difficulties with passengers, stress of road traffic etc.), it would be desirable to reduce the staff requirements of the traffic departments.

With increasing automation in the transport sector this reflects however on the skill requirements of the technical personnel, and the demand for technical personnel. It appears desirable to hold the administrative staff (including management, accounting, scheduling, general planning and legal department) to about 10 % of the total personnel.

1.5.6 Maintenance and Servicing

The amount of maintenance and servicing needed for infrastructure and vehicles varies from system to system. Systems using the traffic space of public roads need a great deal more maintenance and service mainly for their vehicles than other systems. Automated cabin systems may have to spend more on maintenance and servicing of their vehicles and installations than other systems: "automation" in itself involves more maintenance and servicing as installations and vehicles operated without personnel are more exposed to vandalism; with smaller vehicles, the number of parts needing maintenance and servicing is higher (e.g. doors, undercarriages) than with large vehicles.

Operators want systems which need little or no servicing. Maintenance should therefore not be based on fixed overhauling schedules but take into account statistically recorded failure characteristics of parts and components. The proportion of components which can dispense with periodic overhauling should be increased, as in aircraft manufacture, by reducing mechanical wear and increasing the proportion of electric and electronic components. In some areas, the replacement of individual modules may supersede the need for overhauling the entire engine which is usually determined by the weakest component.

Maintenance and servicing being subject to time and mileages run, systems operating on a separate right-of-way should attempt to reach a high rate of system utilisation, in order to keep the amount of maintenance and servicing per million passenger-km as low as possible.

An assessment of maintenance and servicing requirements should consider installations and vehicles separately. Additional criteria are operating concept and vehicle size.

1.5.7 Economic Efficiency (Operating Costs, Capital Costs)

Operating costs comprise of costs for personnel, parts and supplies, and energy; the proportions of these cost items vary from system to system.

Capital costs are expenses for vehicles and infrastructure, assumed for costing purposes; i.e. including depreciation and interests on investment.

For the time being, no public transport system is capable of covering its overall costs from fare and other revenue.

The general practice today is that public funds are provided to cover the capital costs for infrastructure, and as far as possible fare revenue and other income are used to meet vehicle and operating costs. Coverage of vehicle and infrastructure costs by the operator is rarely possible even in the case of systems with minor infrastructure requirements as for bus and tramway systems.

Usage of road space and the space for underground and elevated systems is usually made available to the operators free of charge by the local authorities.

Where transport systems carry certain groups of passengers free of charge, i.e. handicapped persons and pupils, and other groups - commuters, old people, students and other special groups - at reduced fares, or where supervisory authorities or political institutions demand the maintenance of uneconomic services, they should be entitled to compensatory subsidies enabling them to cover their operating costs from fare revenue and other income. It is of general economic interest that the officially prescribed fare policy should not affect the quality of a transport system, in other words, operators should not be limited in operational decisions or when buying new vehicles in replacement of old material.

Capital and operating costs cannot be considered separately. Investments may produce a trade-off in operating costs, such as the construction of separate tracks for bus and tramways; conversely, higher investment of capital can also cause an increase in operating costs if, for instance, an operator must assume the costs for operation and maintenance of tunnels, escalators etc.

A longer life time of vehicles and installations reduces annual capital costs, but with growing age they incur more expense for maintenance and servicing, and become less attractive.

It is therefore necessary to take a comprehensive approach, including the respective proportions of capital and operating costs as well as public funds, and to consider the overall economic costs and consequences.

1.5.8 Suitability for Co-Ordination with other Transport Systems

Primary consideration is given to the problems involved in linking various transport systems and to the physical and organisational requirements of such linkage points. So the problems of compatibility of two systems operating on the same right-of-way, or substitution of a new system for an old one (adaptation of right-of-ways, clearance gauges and vehicle engineering) will not be considered under this Chapter.

A problem of particular importance is interchange of systems with widely different passenger handling capacities, e.g. between high-capacity rapid transit railway systems and a small cabin system. Co-ordination with demand-operated systems is even more difficult as these require certain action on the part of passengers, such as calling of cabin, coding of the destination and dispatching.

Free and smooth interchange between various transport systems is generally considered as a desirable objective. Where it is difficult to interchange transport systems of widely different capacities in major transfer facilities it is preferable to provide a greater number of smaller transfer points in various parts of the networks so as to facilitate interchange from one system to the other.

For an assessment it is necessary to take into account:

- system capacity and
- operating concept.

1.5.9 Adaptability for Technical Progress

Automation has always been a primary interest in the development of transport systems, even more so as constantly rising personnel costs make it necessary to seek ways of reducing personnel requirements. Under this aspect, systems which exclude "fully automated operation" have a certain number of disadvantages as they rule out the possibilities of personnel savings and reduction of the scope for human errors.

The specific advantages of automation can only become effective with systems operating on a separate right-of-way. Therefore, when introducing new systems and enlarging or improving existing ones, careful consideration should be given and allowance made for their potential for future development.

Systems sharing their right-of-way with other modes of transport are not suited for fully automated operation, although improvements along the lines of part-automation may be possible. This is for instance illustrated by certain taxi, dial-a-bus and other bus systems where the quality of service could be improved by automating certain elements of operation. Such improvements can be in the field of information (about departure time and arrival time for systems operating on call) position finding, passenger counting systems, seat reservation and facilities for automatic fare collection.

An assessment of this criterion can be based on the existence of or the financial requirements for the provision of a separate right-of-way essential for the introduction of automated operation.

2. Inventory

2.1. Brief System Descriptions

2.1.1. Break-down

In order to obtain a clear picture of the great number of transport systems in operation or in development for future operation, it may be useful to define groups of transport systems. Definitions can be made on the basis of the various criteria, some of which are:

- capacity
- state of development
- application
- personnel requirements, etc.

A break-down according to the above criteria is, however, subject to modification in the course of time and as a result of technical development (substitution of a capacity increasing line conductor system for a rigid block system). Therefore, preference is given to a break-down based on a combination of several characteristics, such as

- nature of the guideway
- continuous or intermittent operation
- vehicle size
- operating concept (with or without fixed routes).

The nature of the guideway determines whether a transport system requires personnel for its operation or whether it can be operated automatically, without personnel.

Where a transport system is capable of both continuous (e.g. people movers) and non-continuous operation (for longer distances), the break-down is based on the more common mode of operation.

For the purposes of the break-down, vehicle size is mainly considered in combination with the operating concept. Between scheduled services on the one hand and non-scheduled services on the other, x) there are mixtures of operating concepts (such as the dial-a-bus system). The break-down depends on the nature of the service provided, i.e. whether passengers are served on demand and carried directly to their destination without intermediate stops. Another operating concept can be to reduce the number of intermediate stops.

For this purpose, the selected groups, identified by specific passenger vehicles or means of transportation, are briefly described as follows:

Group A: Taxi

This group is represented by vehicles, usually with four passenger seats, driven by a driver on public roads. Passengers are mainly carried individually or in small groups

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x) A scheduled service is a regular service between a given point of origin and a given destination. Passengers can board and/or alight at fixed stops along the route.

and taken directly to their destinations. But it is also possible that individual passengers can be driven to different destinations. In most cases, taxi services are demand operated services without a fixed route pattern.

Group B: Dial-a-Bus

This group includes vehicles with more than 8 passenger seats, driven by a driver on public roads. The radio dispatched buses are either exclusively operated on demand, or on fixed routes adaptable to demand. Unlike systems operating fixed routes according to a schedule, a dial-a-bus system can increase its frequency of service and reduce walking distances and the number of transfers etc. for the benefit of the user.

Group C: Scheduled Bus Services

This group comprises of vehicles usually equipped to carry 50 or more passengers and like taxis and demand buses are driver operated on public roads. In some cases separate bus lanes are available. Where buses are operated on a separate right-of-way, they are classified under another group (group D). Large-capacity vehicles, guided by contact-line and non-track-guided (like trolley buses) are included in the same group as scheduled bus services.

The main difference between a scheduled bus service and a dial-a-bus service is that the former provides regular services between a given point of origin and a given destination (fixed route system).

Group D: Dual-Mode Vehicles

This group covers vehicles which can be operated on public roads under the control of a driver or on a special track under automatic control.

Group E: Track-Guided Small Cabin Systems

These systems are characterized by the existence of an exclusive and separate track on which small vehicles with up to 6 seats are moved automatically without any driving personnel. The operating concept provides for stops and stations, and operation on passenger demand. The route is selected by the passenger, intermediates are not served and the destination exclusively follows the passenger's (individual or in a group) demand.

Group F: Track-Guided Large Cabin Systems

The difference between this group and the small cabin systems is a matter of vehicle size and operating concept and their capacity of being coupled together in the formation of trains. Large cabins can carry between 6 and 50 passengers. Although large cabins can also be operated on demand, they usually pick up a larger number of passengers at various points with different destinations and carry them together on sections or part of a route. In most applications, large cabins are operated on fixed routes and according to a fixed schedule.

Group G: Track-Guided Large-Capacity Vehicles

The vehicles in this group carry 50 and more passengers and are suited for train formation. The operating concept is one of fixed routes served according to a fixed schedule, sometimes also demand-responsive. Whereas small and large cabin systems are operated without personnel, large-capacity vehicles usually require driving and operating personnel.

As the operating concept cannot be used as a characteristic delimiting groups F and G, an arbitrary distinction is made on the basis of passenger carrying capacity ($F \leq 50$, $G > 50$). In the USA, vehicles with a carrying capacity of 100 and more passengers are in service, operating on demand and without driving personnel (Airports Tampa and Miami/Florida). But also conventional large-capacity vehicles can be run without driving personnel so that a distinction on the basis of the operating concept (with/without driving personnel; demand operated or not) would also be arbitrary. In this case it may be necessary to draw the line under the status of development of a given year.

Under both groups can be subsumed systems known as horizontal elevators or shuttle-loop transit systems. They are characterized by demand-responsive operation, simple technical safety concepts, no switching technology, and increased requirements for transfers.

Group H: Continuous Conveyor Systems

This group includes the continuously moving types of transport. Normally passengers are not moved in vehicles and there are no seats provided. These systems move large numbers of passengers on fixed routes but over relatively short distances.

2.1.2 Description of Systems

A comparative evaluation and selection of the various short-distance transport systems presupposes a description of their most important components and characteristics and information about their manufacturers and state of development.

A specially devised questionnaire (Annex 1) is intended to compile comprehensive information of the various systems in a uniform format as an instrument for comparison. These questionnaires will be used for describing the transport systems of groups A to G.

Illustrations and diagrams of vehicles and track elements, switches and stops/stations will complete the information provided by the questionnaires.

The explanatory notes (Annex 2) are intended to facilitate the completion of these questionnaires.

Only a uniform description and presentation of the systems afford meaningful comparison between the various systems of a group, as well as with other groups. System descriptions will be made for a limited number of selected systems, intended to facilitate evaluation in Chapter 3, and to serve as illustration for the readers.

When considering short-distance transport systems, it is necessary to bear in mind that - especially with respect to new systems - different acronyms and names are in use for identical systems, or that they differ only in respect of minor components.

Therefore, when making a selection, the following factors must be borne in mind:

- sometimes the state of development cannot be used as a selection criterion (development may be already discontinued);
- for some systems, only certain components have become known;
- some are only suitable for goods haulage;
- some are suited for specific transport functions only; (shuttle services owing to insufficient switching technology, low speeds etc.; this applies for instance to exhibition ground transport systems, mountain railways etc.);
- some systems exclude a major proportion of special passenger groups from its use (e.g. means of transport which move continuously in vertical direction)

The systems which have passed this screening process will be classified into one of the groups listed under Chapter 2.1.1.

Annex 3 contains descriptions of some selected systems from each group.

2.2 Existing Short-Distance Transport Systems and their Future Development

2.2.1 Existing Short-Distance Transport Systems

Short-distance public transport is characterized by the carriage of passengers against payment, as a commercial enterprise, in motor vehicles or track-bound vehicles, over distances of usually up to 50 km

Short-distance public transport is carried out with:

- tramways, trolley buses, motor buses
- urban and regional rapid transit railways
- special-type railway systems (e.g. mountain railways, cable railways and suspended railways)
- ships
- passenger cars (taxis)

2.2.1.1 Types of Operation

The principle common characteristic of the first four above-listed short-distance systems is the transportation of passengers as a regular service along fixed transport routes, i.e. between given points of departure and given destinations with possibilities for boarding and alighting at fixed intermediate stops. In addition to providing services for all types of passengers, in accordance with their general transport obligation, public transport systems sometimes provide a special form of transportation (special services) for certain categories of users:

- commuters (services between home and work)
- students (services between home and school)
- shopping or recreation trips.

The use of passenger cars as a means of short-distance public transportation over fixed routes is being tested at present. As a rule, in public transport, passenger cars are used only for demand or occasional services, i.e. without fixed stops or stations for boarding and alighting for direct-routing and without intermediate stops. The travel/transport destination is determined by the passenger.

Fixed stops and stations are characteristic criteria of all track-bound systems and ships (landing piers). Conversely, these systems are not suited for demand services from door-to-door.

The type of operation (regular services or demand services) only partly determines the area of application of a short-distance transport system. The taxi, for instance, is a non-track-bound system capable of handling by itself the total transport demand of certain areas (in some cases in towns up to 300 000 inhabitants) or as a supplement to other means of transport.

As a rule, the kind of service provided is determined by the capacity of a system. Suitable for demand traffic are only systems which operate economically at low capacity. On the other hand, where heavy traffic has to be handled over a limited number of routes, a system with a high capacity operating scheduled services along fixed routes should be able to run economically.

2.2.1.2 Applications

Tramways are systems of low flexibility due to their fixed track and overhead contact wires. Accidents or construction works along the route may cause disruption of service and considerable delays for passengers, or may require the provision of alternative bus services. Traffic congestions which reduce effective operating speeds in inner city areas combined with high capital and maintenance costs have led to discontinuation of tramway services in many cities and/or operational changes in others.

Owing to their train forming capability and their large carrying capacity, tramways are mainly used for the handling of heavily concentrated traffic streams in towns and cities with 300,000 to 700,000 inhabitants. Their maximum carrying capacity in most applications is about 15,000 passengers/hour, in each direction per track.

Trolleybuses (buses with overhead contact wires) have remained in operation in only a few cities. Operational shortcomings, such as obstructions of the traffic flow due to the difficulties of overtaking such buses, relatively high capital and maintenance costs, but also aesthetic considerations concerning the overhead wires which are felt to impair the general aspect of the towns have led to the closing down of many trolley bus lines in recent years. Thanks to their good acceleration performance and climbing abilities they are still operated in mountainous areas (Switzerland).

Trolley buses are usually operated in applications overlapping the lower capacity range of tramways.

Buses In the year following the second world war motor buses filled the place of tramways in many cities. They can easily avoid obstructions and adapt smoothly to the traffic flow in the street (acceleration and deceleration capacity). With increasing traffic, these advantages become more and more important.

The motor bus is suited for a wide range of transport jobs. In cities up to 700,000 inhabitants (or even larger in America) it frequently covers the entire public transport service. In cities running an efficient rapid transit railway, it often serves as feeder or distributor system but also as a supplementary system (e.g. double-decker buses in London, express buses in Hamburg). Regular transport services in the open country or in "rural areas" are almost exclusively operated with motor coaches.

The capacity of bus lines is usually low where they must share the roadway of motor traffic, due to traffic signals, incapability for train formation, and time-consuming passenger handling etc. By contrast, on certain routes, motor buses can handle as much as 10,000 passengers per hour in each direction or more (e.g. 26,000 pass/h in each direction on the bus lane of the Freeway-I-495 in New Jersey, by the Lincoln Tunnel). [10].

Urban and regional rapid transit railways, are also known as Métro (Métropolitain), underground railways, tunnel railways and suburban and urban railways. Until the end of the 2nd world war, there were only 19 cities all over the world which ran such a system. Each of these cities had more than one million inhabitants. By the end of 1975, rapid transit railways are in operation in 48 cities (even in cities of 500,000 inhabitants); in another 30 cities such systems are in preparation or under construction. In view of the very high capital costs involved in the construction of rapid transit railways they are justified only for high transport demands. Therefore, one of the main criteria of routing, especially in the outer districts of major cities, is the existence or planning of development axes with a high building density. Depending on the train safety control system and train capacity, rapid transit rail systems reach theoretical carrying capacities of up to 80,000 passenger/hour in each direction (Sao Paulo).

Construction and operation of special-type rail systems are usually conditioned by the special topographical peculiarities of the area in which they operate: mountain railways and cable systems which run across valleys or overcome great height differences. The Wuppertal suspension railway (FRG), for instance, is an elevated guideway system with suspended vehicles built across the Wupper river. Where the average distance between nearby buildings and the guideway is sufficiently wide, the system can be relatively well integrated and assimilated with the prevailing urban aspect. As these special-type rail systems serve specific applications and are frequently limited to handling low or intermittent traffic volumes (e.g. in tourist areas) they need not be given any further consideration as short-distance public transport systems.

The same applies analogously to ships and boats as only a very small proportion of public transport is handled by ship. Even in a city like Hamburg, with large water areas, only 0.8 % of all passenger-kms are operated by ship.

Public transport by passenger motor vehicles (taxis) exists in big cities as well as in small communities. With the present types of vehicles used for this kind of transport, their carrying capacity is not higher than that of private traffic. Therefore, taxis mainly perform a feeder and distributor function in sparsely populated areas or during low traffic hours, sometimes as a regular service along fixed routes, or as a supplementary service for mass transit systems.

2.2.2 Further Developments

Further development of existing short-distance transport systems is intended to bring about technical and operational improvements of the systems. In many respects, system development is as important as component development (e.g. bus).

The two groups "special-type railways" and "ships" will not be considered any further as no appreciable developments are either known in this sector, or the development

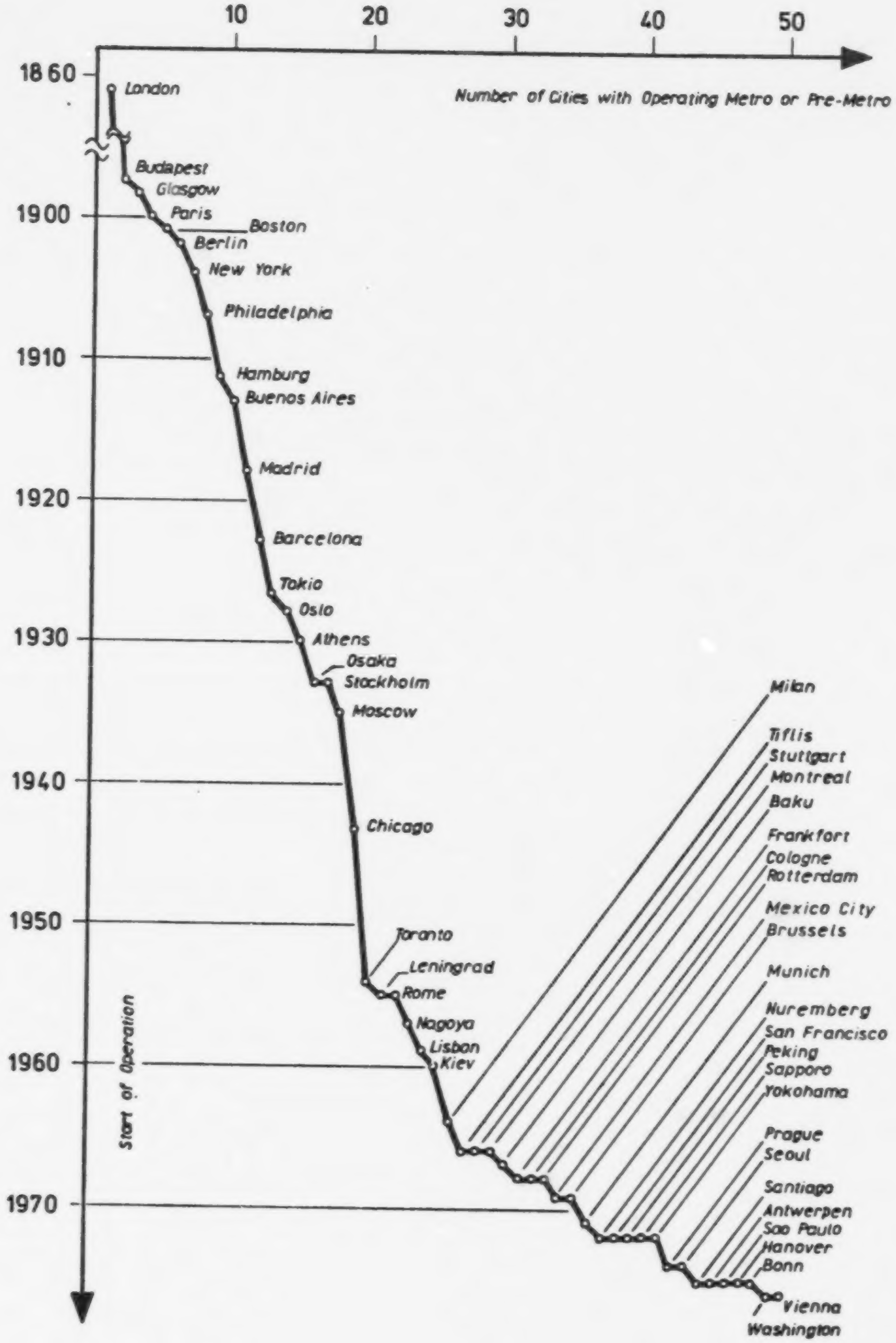
- such as the use of thyristors for suspended railways - can also be dealt with in connection with other system groups such as rapid transit railways.

2.2.2.1 Urban and regional rapid transit rail systems

Rapid transit railway systems built in recent years show a tendency towards broader vehicles and in some cases also broader tracks (in Rio de Janeiro, Sao Paulo, San Francisco, Helsinki). The present trend is in favour of vehicles $\geq$ 2.90 m wide, allowing for 4 comfortable seats arranged in a row transverse to direction of travel. Newly placed orders for public transport vehicles (Berlin, Paris) indicate that there is a change in trend from longitudinally arranged seats to transversely arranged seats. This change results in greater passenger comfort by increasing the seat/standee ratio while maintaining the overall carrying capacity.

In most public transport undertakings, rapid transit trains are formed by two or three units inseparable during operation (married pairs). Maximum train length is generally made up of three units or four double units. If traffic loads require trains to be operated always at the same length (high traffic volumes even during "off-peak" hours - e.g. London), capital costs and capacity losses can be reduced by providing only two driver cabins per long train.

Similar to other transport systems, rapid transit railways also show a trend towards light-weight vehicle construction (aluminium, light-weight steel construction). The light-weight


10
20
30
40
50
Number of Cities with Operating Metro or Pre-Metro
1860
1900
1910
1920
1930
1940
1950
1960
1970
Start of Operation
London
Budapest
Glasgow
Paris
Boston
Berlin
New York
Philadelphia
Hamburg
Buenos Aires
Madrid
Barcelona
Tokio
Oslo
Athens
Osaka
Stockholm
Moscow
Chicago
Toronto
Leningrad
Rome
Nagoya
Lisbon
Kiev
Milan
Tiflis
Stuttgart
Montreal
Baku
Frankfort
Cologne
Rotterdam
Mexico City
Brussels
Munich
Nuremberg
San Francisco
Peking
Sapporo
Yokohama
Prague
Seoul
Santiago
Antwerpen
Sao Paulo
Hanover
Bonn
Vienna
Washington

ratio : the relationship between empty weight and vehicle gross floor area moved from values around 1.0 Mp/m^2 (old underground trains in New York) to 0.346 Mp/m^2 (underground vehicles in Toronto). The specific values achieved are influenced by the fitting out of the underground trains by equipment for passenger convenience, the amount of buffer pressure to be absorbed, length and width of vehicles, noise-insulation and anti-corrosion protection. With good equipment, a value of 0.5 Mp/m^2 can be achieved.

The use of glass-fibre reinforced plastic materials for non-supporting components, for interior lining, for seats and for moulded roof parts, for the front and rear parts of vehicles is likely to become standard equipment in the future.

Moving towards higher transit speeds, the steel wheel/rail technology is pushing towards the limits of static friction while maintaining the comfort requirements for standing passengers. Nearly all rapid transit trains now reach maximum accelerations at take-off of 1.3 m/s^2. The specific driving capacity - i.e. the relationship between driving power and empty or total weight of the vehicle - is increasing, when related to empty weight. This means, among other things, higher maximum speeds. Compared with former values of 10 KW/Mp(empty), more recently purchased material scores as follows:

City	Power Rating KW/Mp_{empty}	V_{max}	Year of Purchase
Hamburg	14,0	80	1971
München	15,4	80	1971
San Francisco	17,6	130	1972
Sao Paulo	20,3	100	1974
Rio de Janeiro	20,3	100	1975

As the static friction coefficients drop to extremely low values of $\mu = 0.05$ in the event of wet, oily or smeared rails, special measures are needed to ensure high take-off accelerations. Furthermore, to avoid skidding or slipping of the wheels, it is recommended not to use the "sanding method" as with tramways, considering that

- the rail-head is rounder (i.e. more sand is falling aside than with grooved rails)
- with ballast-free as well as with ballast permanent ways, sanding entails extensive cleaning of the rails and/or track bed elevation
- sanding may also involve the sanding of switches and other safety relevant operational installations;
- the intermittent losses of contact at wheel contact points may result in loss of continuity in rail circuits and thus in signal interference or failures.

Other measures to increase the static friction are:

a) removal of the "greasy film" by means of high-pressure water jets, plasma torches or spraying with chemical solvents ("μ - Plus");

b) development of new combinations of metallic materials for rails and wheels whose static friction are less affected by humidity;

c) protection of open-air guideways against weather influence, by fitting a form of transparent pipe cladding.

In the FRG, track-cleaning is done by high-pressure water jets from maintenance vehicles. However, wheel slipping cannot be entirely avoided. In France and Great Britain tests have been carried out with plasma torches.

Special studies are devoted in the Federal Republic of Germany to the development of new combinations of metallic materials.

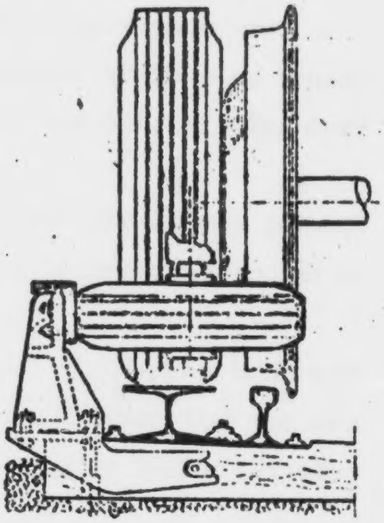
The first completely covered track, including the outer districts, was put into operation in Japan in 1966. It belongs to the rubber-wheeled Sapporo underground railway.

The following measures help to reduce adhesion:

1. all-axle drive, i. e. at 100% friction weight,
2. reduction of weight-transfers
3. reduction of switching impulses, torque vibrations and traction and braking power differentials between the various vehicles of a train;
4. evenly graduated action of the tractive and braking forces, (limitation of jerks, fine-step load-sensitive or infinitely variable starting and braking controls, reduction of the starting torque within the area of resistance and increase of the torque in the characteristic curve);

5. quickly and reliably functioning anti-skid and anti-slip devices,
6. use of electro-magnetic rail brakes.

For higher adhesion, and particularly for smoother running performance and lower noise development, some lines of the Metro in Paris, but also some of the newer rapid transit systems in Montreal, Sapporo, Mexico-City and Santiago de Chile are equipped or will be equipped with rubber wheels for support and guidance. The bogies - with the exception of the Sapporo railway - are additionally fitted with four flanged steel wheels. This development has run into the following problems:



- the cost of the bogie design is relatively high;
- the maintenance and repair requirements for bogies are high (faster wear of the rubber wheels)
- the rubber tyres may involve the risk of failures and even fire (e. g. Montreal 1972)
- the higher track resistance results in higher energy consumption.

The adhesive value being such an important factor - especially with a view to fully automated operation - this opens good perspectives for the future use of linear induction motors designed for contactless magnetic power transmission. One considerable disadvantage of the linear induction motor is its reduced efficiency and drop in power with growing air gap between its primary part on the vehicle and its secondary part on the guideway (e.g. copper or aluminium rail sitting vertically in the middle of the track). To achieve a smaller air gap, it is necessary to provide a non-rigid suspension of the primary part because of the relatively strong vehicle movements on the track. They are conditioned by the guidance system (conical wheel set), and can be reduced only minimally at considerable expense.

Transport operators are continuously endeavouring to reduce the noise levels of urban rapid transit systems. Their efforts directed at the vehicles and the tracks alike may result in certain improvements. Vehicle-related efforts in this context are concerned with:

- the undercarriage (e.g. rubber suspended wheel sets)
- drive and supplementary units (e.g. suspension of the engines, dampening of compressors and switching gears),
- insulation of the passenger compartment (e.g. hermetical sealing, no opening of windows and doors for ventilation which however implies the need for air conditioning).

Efforts concerning the track are:

- improvement of the permanent way (rail, rail coating, rail support and bedding)
- sound absorbing walls.

The construction of a ballast-free permanent way providing better dampening than ballast permanent way is more expensive than the latter. On the other hand, it can bring about savings owing to lower construction levels in tunnels and possibly also through less maintenance.

Further noteworthy developments in the field of rapid transit railways:

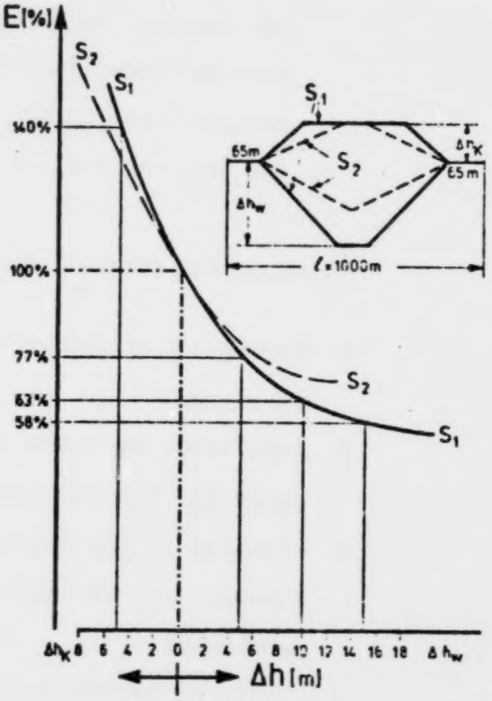
- improvements of the direct current motor
- studies on the use of three-phase motors
- studies on the operational use of d.c. regulator technology (cf. paragraph dealing with the use of thyristors for tramways, Chapter 2.2.2.2)
- use of switches with moving frogs
- measures facilitating the introduction of fully automated or partly automated operation (as below).

An important requirement from the operational viewpoint is the construction, wherever possible, of "humping stations" for new underground railways i.e. where the stations are at higher levels than the route track. Studies conducted in Hamburg have indicated [16] that such an arrangement has the following advantages:

- up to 40% and more in energy savings
- an increased system efficiency
- reduction of transit times by lower starting resistances and higher braking resistances
- a reduction in waste heat owing to lower energy consumption.

The following relationship has been found for a ridge or a trough situated between two stations. The energy consumption of a train running on a horizontal track between two stations ($\Delta h = 0$) is assumed as 100%:

s = inclination
h = difference in level between the two stations
E = energy consumption
l = distance between the two stations
Δh_K = difference in level for a ridge
Δh_W = difference in level for a trough



Reduced maintenance costs are likely to result from

- standardisation of vehicles and equipment/installations
- development of automated fault-finding diagnostic procedures.

- installation of maintenance free or low-maintenance vehicle components and equipment
- mechanisation or part-mechanisation of permanent way construction and maintenance.

A further aim is the reduction of the transport personnel costs through maximum automation of operation. This may however result in additional costs

- for regular maintenance of the automatic machines
- for the maintenance of surveillance or passenger information equipment, vehicles and installations
- for the removal of damages caused by vandalism.

Existing and planned measures towards automation of operation:

1. Setting-up of ticket-vending machines thus reducing sales personnel
2. Automatic barriers at the entry and possibly also at exit gates for the reduction of control personnel
3. Changes in the train dispatch system saving station personnel, or, as applicable, station dispatchers and train personnel
4. Fully or partly automated running for relief or, as appropriate, saving of driving personnel.

Nearly all rapid transit systems operate with ticket vending machines. They are particularly effective at points with low traffic density in that they allow immediate personnel savings. At stations with high traffic demand, personnel must be kept for the sale of season tickets and for information, despite the existence of ticket machines.

Most ticket machines meet the requirements of the users as well as those of operators to a large extent: they accept different sizes of coins, they return the change from a self-refilling intermediate store, they are easy to handle, safeguarded against loss and signal failures or interference.

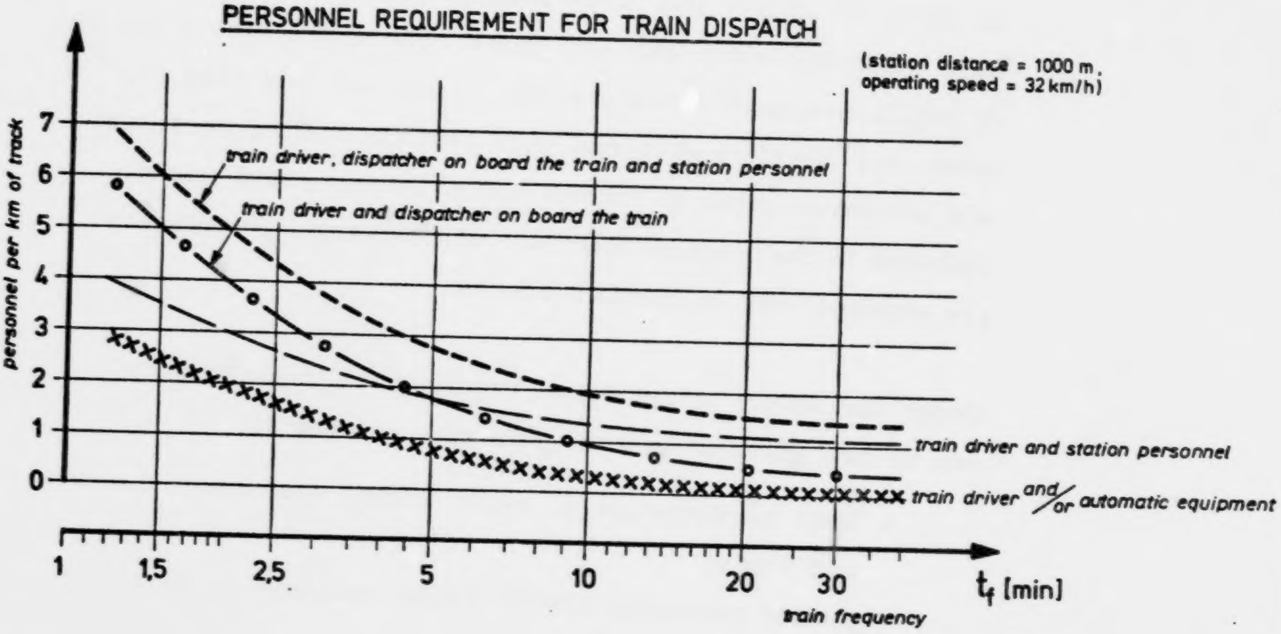
Some rapid transit systems, as London Transport, have automatic gates only at the entries. At the exists, ticket controllers check and collect the tickets. New rapid transit systems, such as the R.E.R. (Réseau Express Régional) in Paris or BART (Bay Area Rapid Transit) in San Francisco have automatic entry and exit gates. There are also a number of public transport operators who do not see any need for gates and therefore dispense with both controlling personnel and automatic gates at entries and exits (all rapid transit railways in the Federal Republic of Germany). Passengers are checked only by random checks.

Under the aspect of personnel requirement, train dispatch can be broken-down into the following categories:

- train personnel (e.g. rapid transit systems in London and Paris)
- station personnel (rapid transit railways in Hamburg and Berlin),
- personnel in dispatch centres separated from the stations (planned for the underground railways in Helsinki and Hamburg)
- train driver (e.g. underground railways in Munich and Stockholm)

- automatic dispatch equipment (e.g. rapid transit systems in Frankfurt and San Francisco).

The minimum personnel requirement of a system is determined by the density of stations in the network and train frequency. For instance, with a train frequency of less than 5 minutes and a station distance of 1,000 m, one dispatcher per station results in a lower personnel requirement when compared with a system utilizing both driver and dispatcher on board each train.



For fully or partly automated operation, vehicles and track must be equipped accordingly. The concept of continuous automatic train running control comprises a number of different possibilities, among which short and long looped continuous signalling systems are among the most widely spread track equipments.

In addition to relieving and/or saving the entire driving personnel or perhaps 50 % of the driving personnel, continuous automatic train running control can bring about the following improvements:

- higher traveling speeds by avoiding time losses from braking
- greater economy through lower energy consumption (optimized running)
- increased maximum efficiency.

Higher efficiency is directly related to shorter train intervals which can be achieved not only by continuous automatic train-running control but also by the following other measures:

- reduction of the safety distances behind signals by installation of speed measuring sections or speed measuring points at signals
- installation of supplementary "move-up" signals which reduce the block signal distance and give clear line only if a certain maximum speed is not exceeded.
- installation of driver's cabin signals
- reduction of stopping times in stations/stops, e. g. through automatic shutting of doors with previous announcement (experimental operation in Paris)
- engineering measures in respect of tracks and vehicles (e. g. removal of slow-down sections, increase of power rating).

Automatic driving permits exact stopping (in Hamburg the tests with automatic operation indicated that fixed stopping points were reached with an exactitude of ± 0. 5 m). Absolute coordination between the doors of the platforms and those of the halting may cause operational difficulties (such as experienced by the Metro system in Leningrad). Time losses are caused by slow approach in order to obtain exact synchronization between platform doors and vehicle doors. This solution suggests itself, in particular, in all cases where vehicles and platforms are air conditioned.

A further development is the completion of a rapid transit network by an express train network. Following the example of New York, where on a four-track line the regular rapid transit trains are complemented by express trains which serve only a certain number of major stations, a similar system was developed in Paris with the construction of the R.E.R network. The R.E.R network consists of new lines in the outer districts of the City of Paris; there are wide distances between stations in the inner city area which are linked with major stations of the existing Metro network, thus ensuring a good coverage of the inner city.

2.2.2.2 Tramways

Worth mentioning among the further developments in this area are partly automated vehicle control and anti-skid and -slip devices for the vehicles. The functions of a mechanical control circuit are replaced by a contact-free and wear-free control unit. Driving and braking commands are effected by the displacement of a small control lever. This means work facilitation for the driving personnel and greater safety, but also greater riding comfort for the traveling public owing to low jerk values during operation.

The use of thyristor-d.c. regulators involves energy savings during take-off and energy recovery during braking. Moreover, they contribute towards higher speeds, made possible by better utilisation of the adhesive forces with infinitely variable starting- and braking forces, greater safety (shorter braking distances through shorter skidding paths) and lower maintenance cost (less wear on wheels and rails). These improvements have an impact on power supply, signalling and communications units, require additional installations in low-voltage stations and in vehicles and may cause operational problems.

Vehicle construction is increasingly benefiting from the know-how available in the fields of aluminium and synthetic light-weight material construction. Rubber-supported wheels improve riding comfort and reduce noise.

In the field of track engineering, further developments exist in respect of ballast-free roadbeds, new grooved rails and grooved rail switches with moving frogs. If facing points of grooved rails are safely locked and their locking maintained, the normal switch travel speed (15 km/h) can be increased.

In the operational field, the most important development in recent years, roughly since 1960, has been the change-over to one-man operation. There is at present also a tendency to replacing four-axled powered cars with trailer or six-axled powered cars (converted/extended) by eight-axled units. For experimental purposes, ten-axled vehicles are being manufacturing. The vehicles are equipped with a vehicle control system providing for the coupling together of 2 or 3 vehicles into a train.

Steps taken in the fields of civil and traffic engineering can increase transport and turn-round speeds. They consist first of all in grade separation of traffic in city centres and provision of separate tracks within the road space, outside the city centres. Further measures may consist in modifying the phasing of traffic lights for private transport, or simple measures of traffic regulation (marking of restricted areas, no left-turns etc.).

The standard tramway system operates vehicles with doors on one side only. However, operation on a separate - underground or elevated - right-of-way, or operational reasons (possibility for U-turns on loops) make it necessary to change over to vehicles equipped with doors on both sides. This is also the case when switching from tramway traffic to a rapid urban transit system.

Further technical and operational improvements likely to enhance the attractiveness of tramways are:

- construction of higher platforms in order to facilitate boarding and alighting (no steps between platform and vehicle floor); this can also be done along public roads;

- improvements of stops and stations; in particular by providing better weather protection and passenger information;
- greater vehicle attractiveness by improved seating arrangements, air conditioning (also in the moderate climatic zones of Europe) and noise insulation;
- standardisation of handling equipment (information equipment, vending machines etc.) and vehicles.

2.2.2.3 Dual-Mode-Buses

While dial-a-bus systems have to be considered mainly under operational aspects as a system permitting door-to-door services, dual-mode systems are characterized by the presence of additional technical components ensuring vehicle lateral guidance by other means than steering and static friction. This additional lateral guidance system can either be positive (horizontal guide wheels, flanged steel wheels), non-positive (vertical wheels/steering), magnetic or pneumatic.

The following solutions are known so far [14]:

1. Two tandem arranged double flanged wheels running on a rail in the middle of the guideway. Name of system: Autobus Guidé (F).

1a. Like 1. with additional horizontal balancing wheels, running along two lateral rails above the vehicle top. Name of system: Wick's Bi-Modal Monorail (GB)

2. One or two antennae guiding the vehicle along an a.c.-powered guide cable in the guideway, by acting on the steering of the wheels.

Names of systems: Automatic Highway (GB)
Metro Guideway (USA)
Donas 20 (FRG)
Dual-Mode Transit System of General Motors (USA).

3. A guide arm which can be lowered into a groove running in the middle of the guideway acts on the steering of the front wheels.
   Names of systems: BMC-BJ-Mode, Guided Busway and Throughway System (all GB)
   Mc Kenzie-System (NZ).

4. The supporting wheels (in road traffic) can take over the guidance function by tilting them by 90°. On the guideway, the vehicle is supported and driven by air cushion.
   Name of system: Hover Bus (GB).

5. Buses are driven onto railway flat cars over endloading ramps; electric drive similar to urban railways.
   Name of system: Huckepack-Bus (FRG).

5a. An electrically driven chassis with pneumatic supports (air cushion), and positive lateral guidance assembly (horizontal rubber wheels) carries a pallet which in turn carries the bus.
   Name of system: Dual Mode Transit System of TTI OTIS (USA).

6. The rubber wheels of the road vehicle are fitted with extensible flanged steel wheels of a chassis for normal rail operation.
   Name of system: Rail-Bus (USA).

7. Vehicle body and undercarriage are connected by a central stem running in a groove thus absorbing the lateral forces. The guideway is below the grooved level.
   Name of system: STARR-Bus (USA).

8. Horizontal, swing-out rubber wheels for lateral guidance running along the lateral walls of the guideway. Additional rubber wheels for switch guidance.
   Name of systems: Dual Mode Transit System Rohr Ind. Inc. (USA)
   Strada Guidata (I).

There are also combinations between the various solutions, some of which help to improve operational safety. For instance, the General Motors designed Dual Mode Transit System is a combination of solutions 2 and 3, providing for mechanically secured switching by means of a roller fitted guide arm running in a groove, in addition to frequency changes at switches effected by a second high-frequency cable in the guideway [15].

During the early conception phase of dual mode developments, about 10 years ago, great importance was attributed to this system because of its potential for automatic and driverless operation by virtue of side guidance and a separate, protected guideway. Personnel savings through driverless operation presuppose, however, a large proportion of separate and protected guideway in the network. At the change-over points from road operation to separate guideway, and vice versa, considerable time losses arise for the operating personnel from

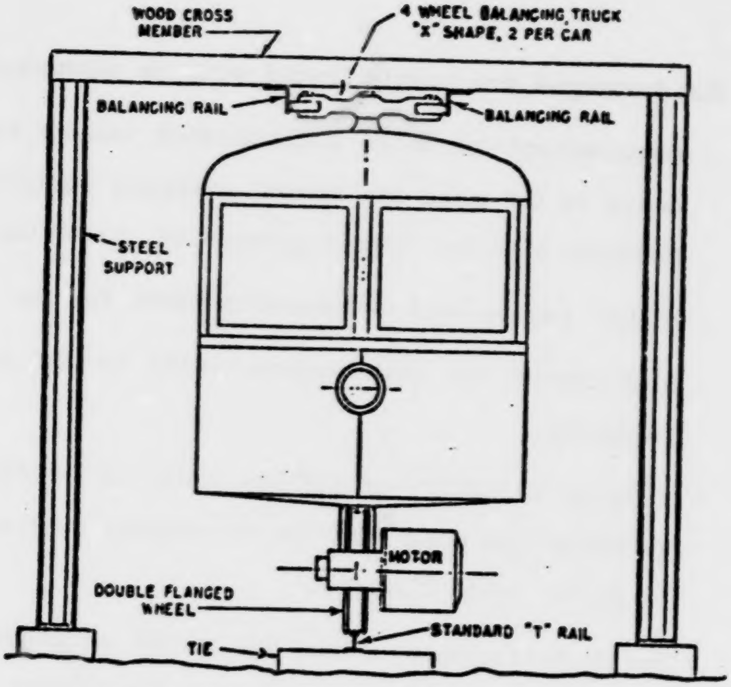
- the need to walk along platforms or from one platform to another
- switching of installations from automatic to "manual" operation and vice versa (e. g. seat adjustment, adjustment of side mirrors),
- installation or removal of certain operator equipment, ticket-collecting cash-box etc.
- delays accruing mainly during road operation but also along separate track when traffic is heavy.

The advantages of dual mode systems are:

- concentration of great traffic streams by means of vehicles equipped with hybrid propulsion systems and capable of non-pollutant operation in the inner city areas;
- a possible reduction of the number of transfers and consequently :
- higher transit or traveling speeds
- provision for an additional traffic level by building an underground or elevated guideway in the inner city areas;
- requirement for smaller clear widths than in the road
- ability to utilise existing road network in low-density areas while maintaining the operational flexibility of the bus.

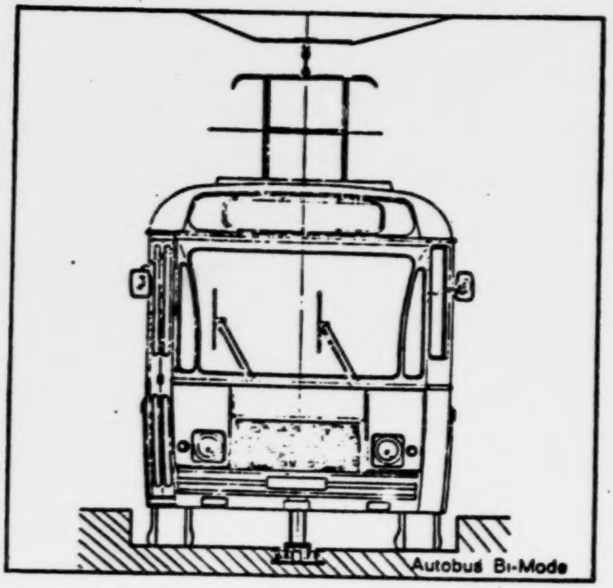
Its disadvantages are partly linked with its advantages:

- requirement for more sophisticated vehicle engineering owing to the need for lateral guidance equipment and possibly also for hybrid propulsion, involving
- higher capital and maintenance costs for the vehicles,
- high capital and maintenance outlay for the separate guideway,
- reduced flexibility of the bus while on its separate guideway (no possibility of by-passing obstructions or of minor route changes),
- lower development effect due to the necessary concentration of traffic along one or a few routes.


WOOD CROSS MEMBER
4 WHEEL BALANCING TRUCK "X" SHAPE, 2 PER CAR
BALANCING RAIL
BALANCING RAIL
STEEL SUPPORT
MOTOR
DOUBLE FLANGED WHEEL
STANDARD "T" RAIL
TIE

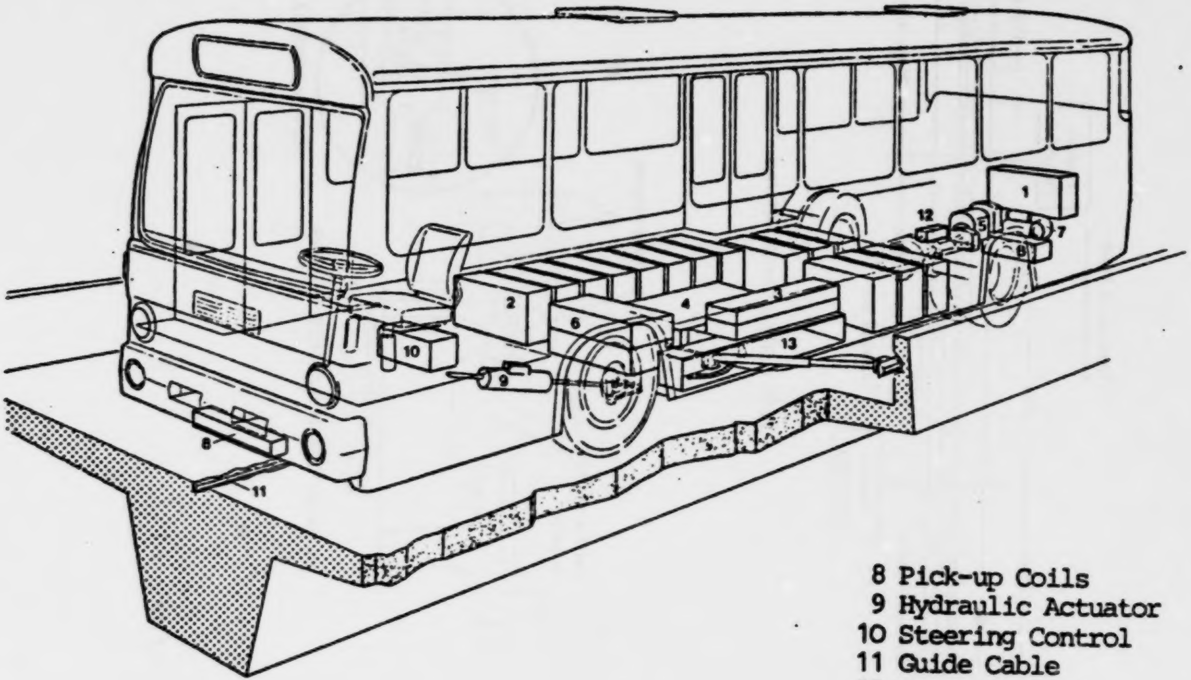
Wick's Bi-Modal Monorail

Source: [14]


Autobus Bi-Mode

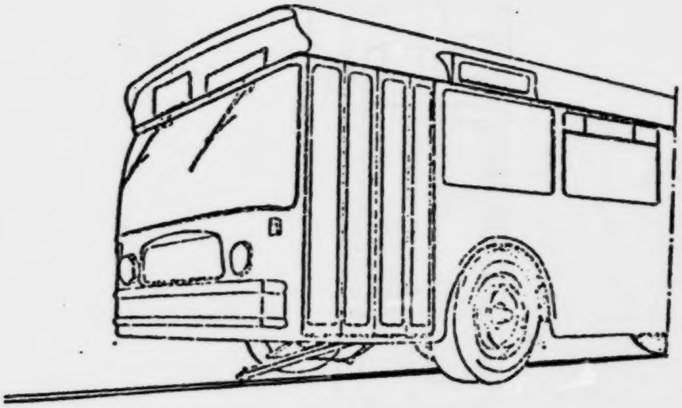
Autobus Bi-Mode

Source: UITP REVUE Nr. 4/1975 p.286



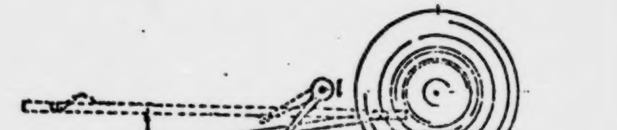
8 Pick-up Coils
9 Hydraulic Actuator
10 Steering Control
11 Guide Cable
13 Power Pick-up

Dual-mode-System
(Concept: Dornier System) Source: [17]

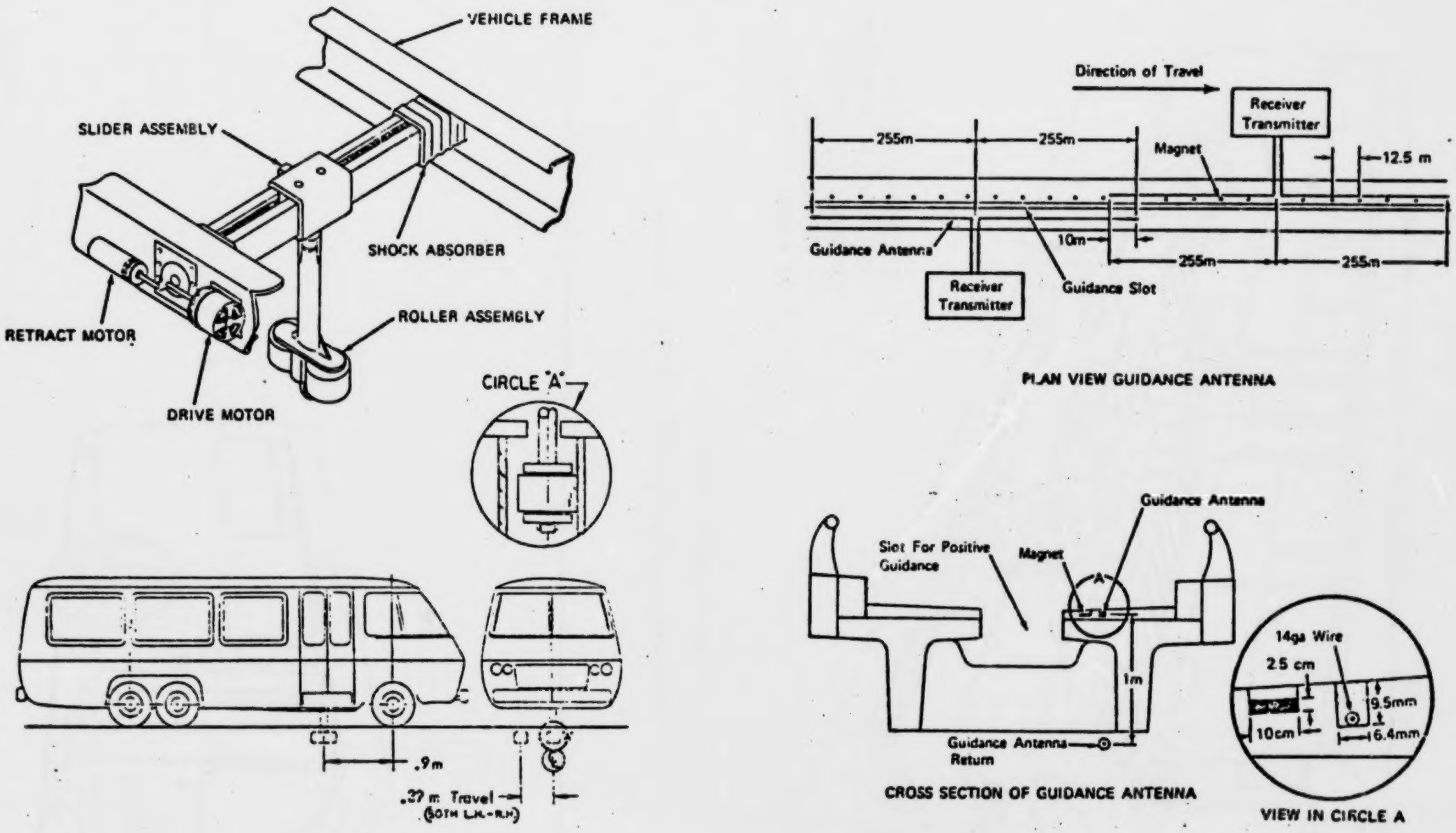


Throughway System

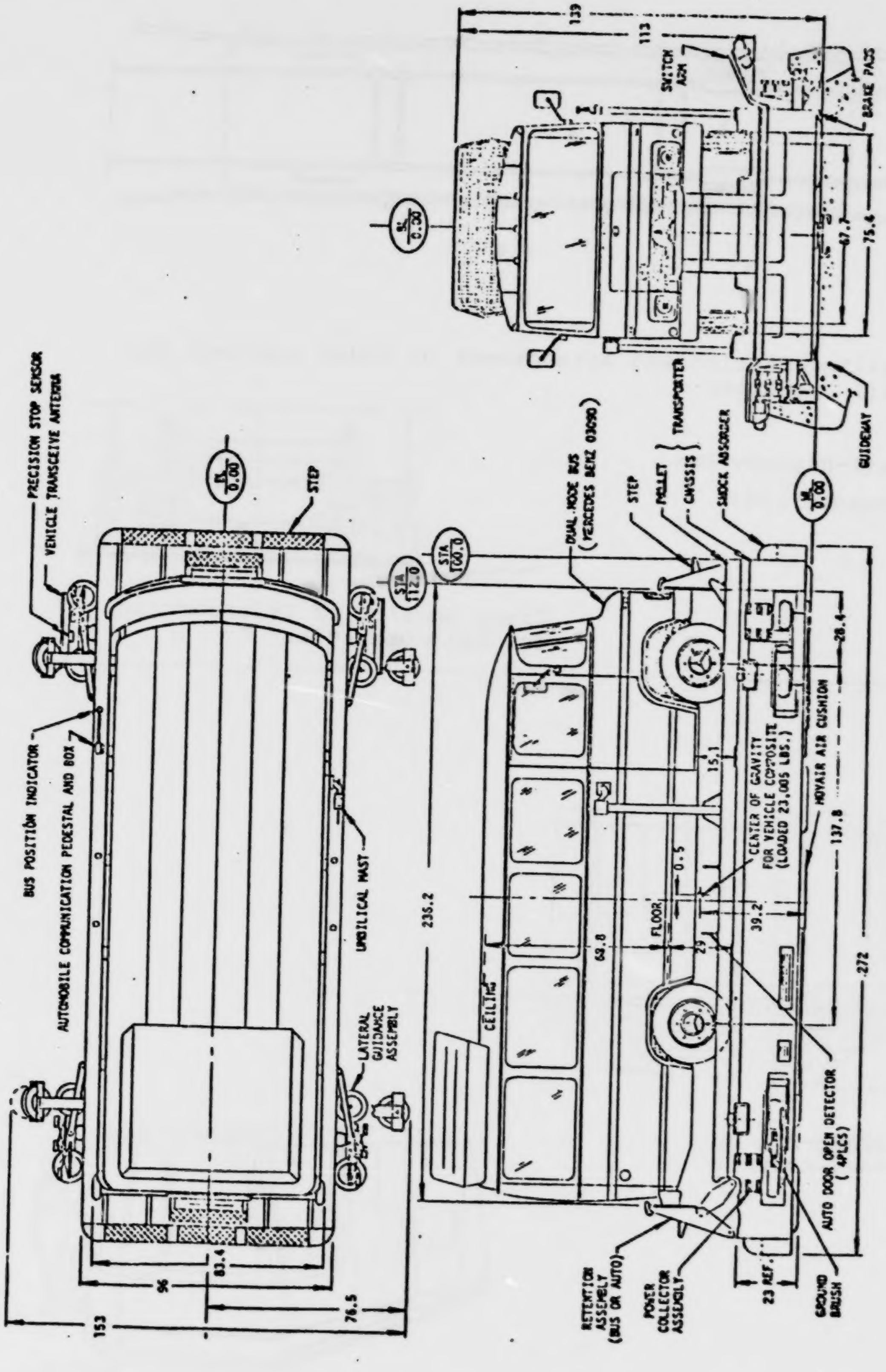
Source: [14]



Detail

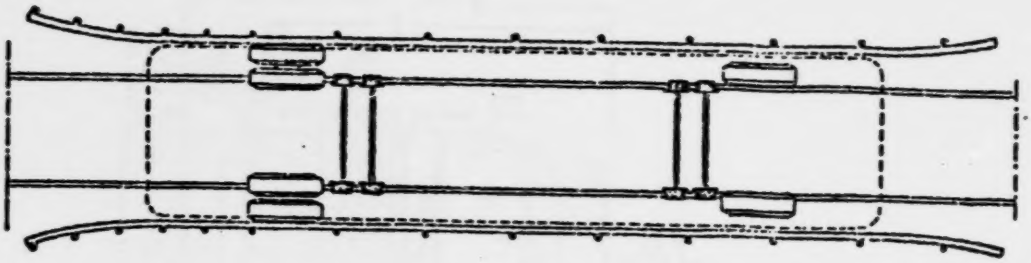

VEHICLE FRAME
SLIDER ASSEMBLY
SHOCK ABSORBER
RETRACT MOTOR
ROLLER ASSEMBLY
DRIVE MOTOR
CIRCLE "A"
.9m
.37 m Travel
(BOTH LH-RH)
Direction of Travel
Receiver Transmitter
255m
255m
Magnet
12.5 m
10m
255m
255m
Guidance Antenna
Receiver Transmitter
Guidance Slot
PLAN VIEW GUIDANCE ANTENNA
Guidance Antenna
Slot For Positive Guidance
Magnet
"A"
1m
Guidance Antenna Return
CROSS SECTION OF GUIDANCE ANTENNA
14ga Wire
2.5 cm
9.5mm
10cm
6.4mm
VIEW IN CIRCLE A

Dual-mode-System
(Concept: General Motors) Source: [15]


BUS POSITION INDICATOR
AUTOMOBILE COMMUNICATION PEDESTAL AND BOX
PRECISION STOP SENSOR
VEHICLE TRANSCEIVE ANTENNA
STEP
UMBILICAL MAST
LATERAL GUIDANCE ASSEMBLY
153
96
83.4
76.5
STA 112.0
STA 160.0
DUAL-MODE BUS (MERCEDES BENZ 03090)
STEP
PALLET
CHASSIS
TRANSPORTER
SHOCK ABSORBER
CEILING
FLOOR
235.2
68.8
29
39.2
0.5
15.1
137.8
28.4
272
23 REF.
CENTER OF GRAVITY FOR VEHICLE COMPOSITE (LOADED 23,005 LBS.)
HOVAIR AIR CUSHION
AUTO DOOR OPEN DETECTOR (4PLCS)
RETENTION ASSEMBLY (BUS OR AUTO)
POWER COLLECTOR ASSEMBLY
GROUND BRUSH
139
113
SWITCH ARM
BRAKE PADS
GUIDEWAY
67.7
75.4
0.00

Dual-mode-System

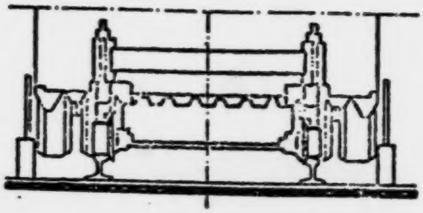
(Concept: TTI OTIS) Source: [15]



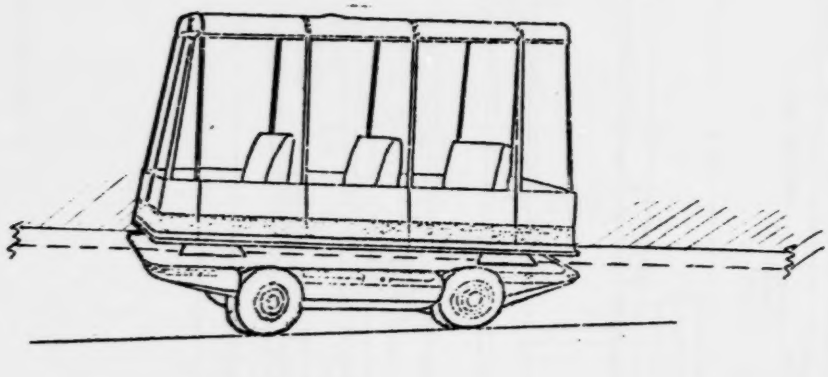
Railing Station and Arrangement of Under carriage for Rail Operation

Rail-Highway-Bus

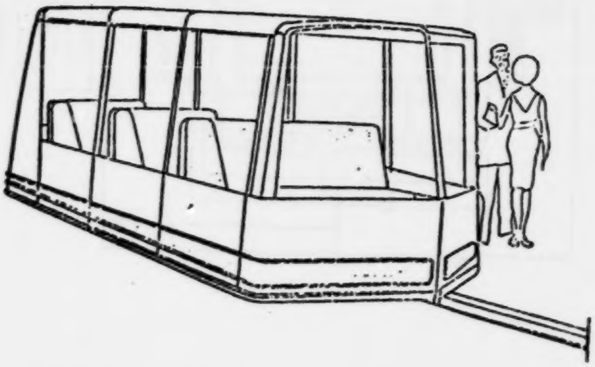
Source: [14]



Cross Section of Undercarriage for Rail Operation

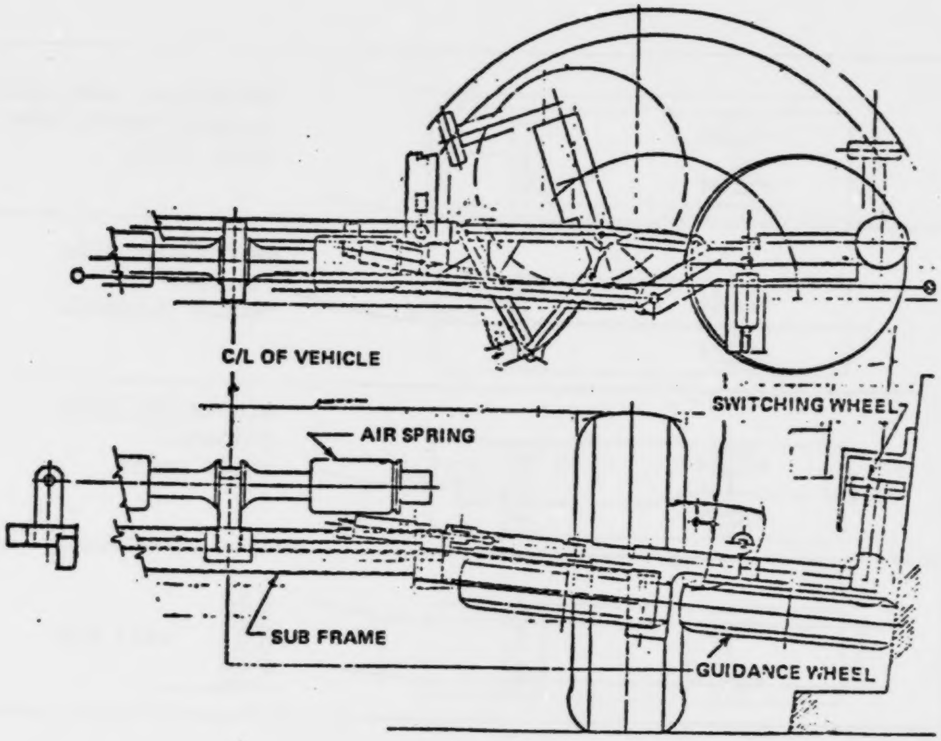


STARR-Bus on Road-Surface

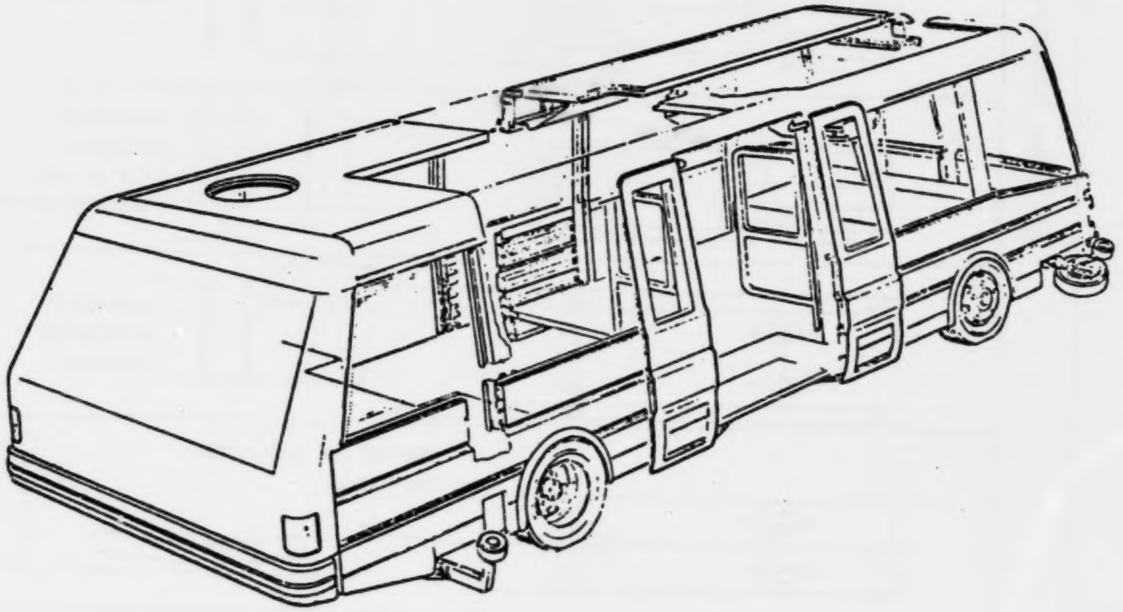


and on Track in a Station

Source: [14]

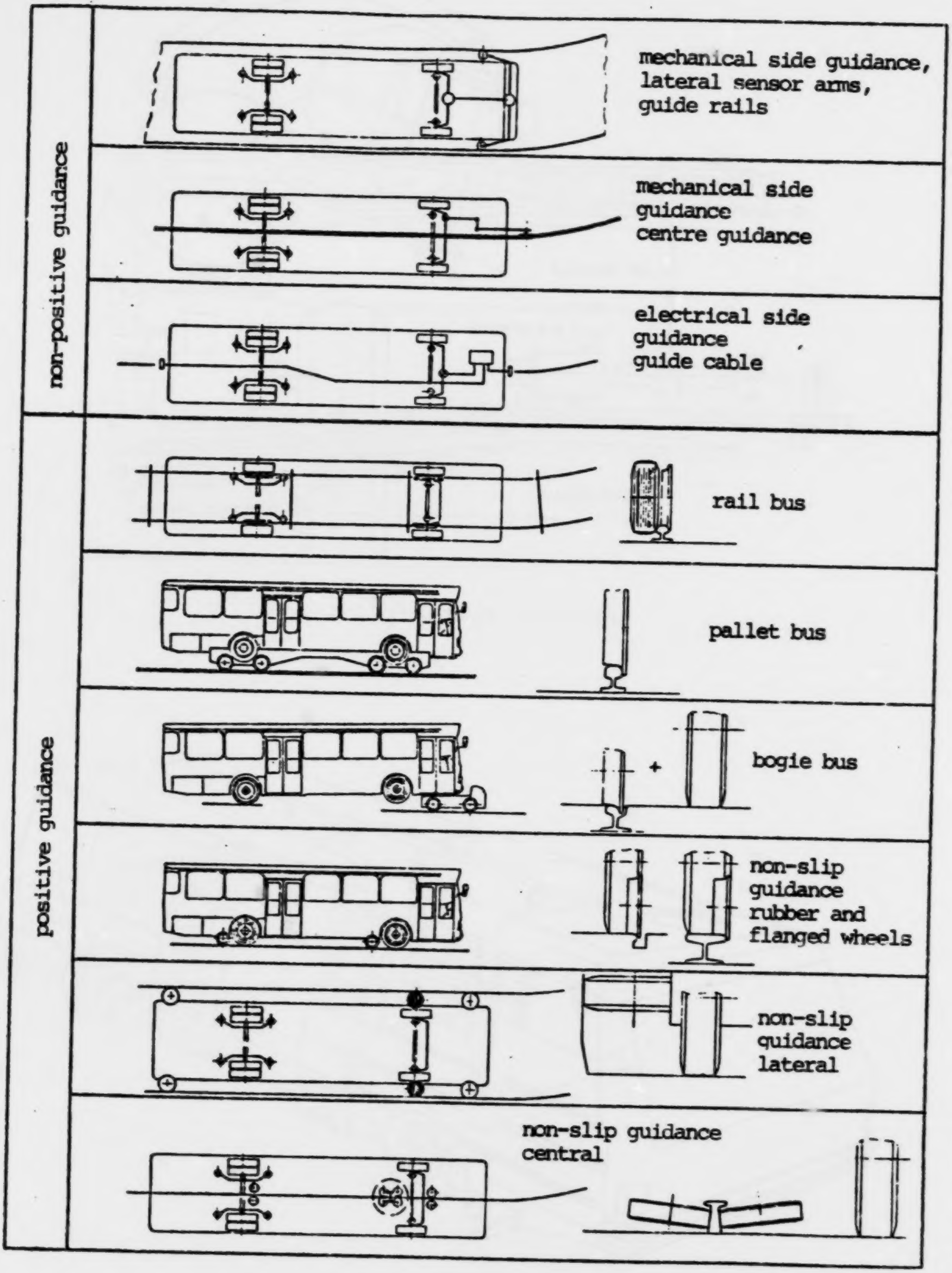

C/L OF VEHICLE
SWITCHING WHEEL
AIR SPRING
SUB FRAME
GUIDANCE WHEEL

Guidance System Front



Dual-mode-vehicle
(Concept: Rohr Ind. Inc.)

Source: [15]


non-positive guidance
mechanical side guidance, lateral sensor arms, guide rails
mechanical side guidance centre guidance
electrical side guidance guide cable
positive guidance
rail bus
pallet bus
+
bogie bus
non-slip guidance rubber and flanged wheels
non-slip guidance lateral
non-slip guidance central

Dual-Mode Systems (survey)

Source: [17]

2.2.2.4 Trolley Buses

Among the technical improvements there is, like in the field of tramways, the use of direct current regulators. They provide for infinitely variable regulation of the tractive and braking forces thus

- avoiding the slipping of the drive wheels, and allowing for simpler and lighter drive axles;
- ensuring smooth starting and braking;
- reducing maintenance and energy costs - especially when using the regenerative braking system;
- allowing for intermittent battery-driven operation without overhead contact wire.

New vehicles have, for the greatest part, already electronically controlled acceleration and deceleration controls. If direct current regulators are in use, there is no more need for the rather heavy and less robust compound motor, so far necessary for technical reasons for regenerative braking.

With future trolley buses it will be possible to reduce to some extent, at least temporarily, the disadvantages of the overhead contact wire by equipping them with low-powered auxiliary engines. This will facilitate shunting in the depots, as well as by-passing of construction sites and other major obstacles. At present, the following auxiliary units are in use:

- gasoline engine of a small passenger car (in Solingen)
- Diesel engine of a small passenger car (in Milano)
- lead storage battery with an auxiliary switching apparatus (in Geneva).

If the operating concept provides for regular operation with and without overhead contact, the bus must be equipped with a more powerful auxiliary engine; in this case, the trolley bus becomes a bus with a hybrid energy supply or a hybrid propulsion system. It has advantages for passengers and operators alike, as it combines the flexibility of the motor bus in the outer districts with the advantages of the trolley bus, i.e. overhead infrastructure is limited to the inner city area where it can be adapted to higher traffic flows by network structure and higher vehicle frequency.

Major operational advantages such as time savings and work facilitation for the drivers may be expected from current developments in the field of automatic power pick-up control (in experimental stage in the Federal Republic of Germany) [11]. During a stop in the station, the driver can, from his seat, by pressing a button, automatically make and break the electrical contact with the overhead power line within 15 seconds.

Switzerland is now encouraging the development of articulated trolley buses with a view to reducing the high cost per seat- and passenger-km of bus services.

2.2.2.5 Motor Buses

Improved passenger convenience for boarding and alighting can be obtained from

- low vehicle floors (fewer steps)
- optimum pitch (riser - tread = 12 cm)
- sufficient number and width of doors

for running from the

- use of automatic gears
- use of load-sensitive shock absorbers (air cushioning)

for seating and surrounding convenience from

- sufficiently broad and comfortably designed seats
- good visibility towards the outside for seated and standing passengers
- noise reduction through encapsulation of the engine compartment
- air conditioning.

In addition to the technical improvements aiming at a higher passenger comfort there are also important developments concerned with cleaner, quieter yet economic propulsion systems. There are various reasons why the development of cleaner, quieter and more efficient propulsion systems is encouraged:

- growing public awareness of the environment
- the energy crisis (supply problems for mineral oil products)
- stricter type approval regulations (stricter directives for vehicle manufacturers - the exhaust gas emission rules in force in the State of California are for instance complied with by vehicle manufacturers).

The following list gives a survey of the various types of propulsion systems and their possible combinations.

Diesel engines are, for the time being, still the most economical propulsion system for buses. There is still scope for improvements in the field of exhaust gas emission, but these have an impact on the consumption of energy.

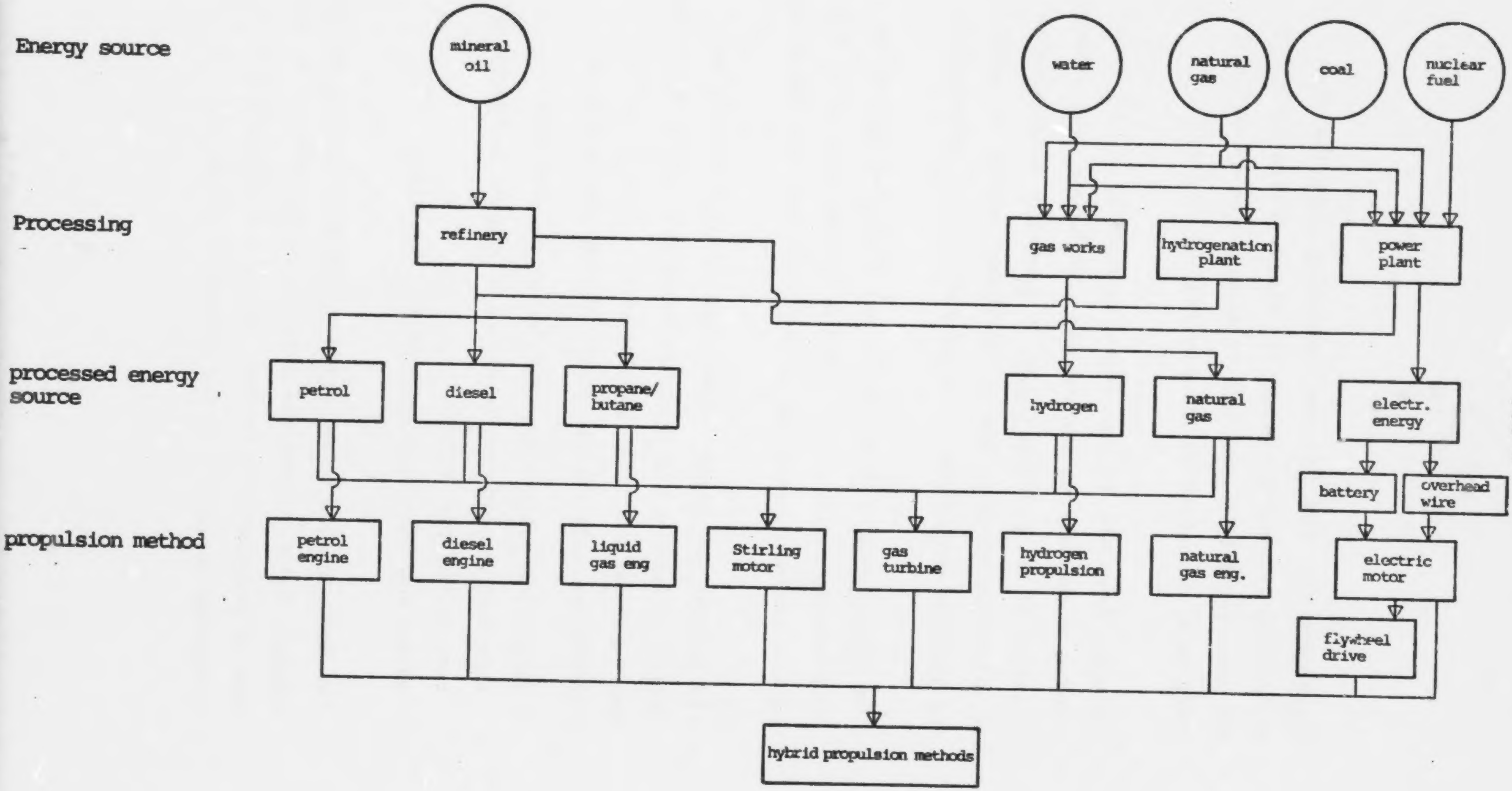
Although there are still no objective criteria on the harmfulness of the various exhaust gas components, the exhaust emission of the gasoline engine is generally considered to be more noxious than that of the Diesel engine. In addition, the gasoline engine has a higher specific fuel consumption.

The Wankel engine (i. e. the rotary piston as against the reciprocating piston of the gasoline engine) also rates higher exhaust emissions and fuel consumption than the Diesel engine.

The natural gas engine constitutes an improvement with regard to exhaust gas emission (especially lower fume and smell values) and noise development.
Factors opposing the use of the natural gas engine are:

- weight and space requirements for the fuel tank
- high fuel consumption (about 15 % related to energy content)
- cost of fuel per Mcal
- safety and time requirements for refuelling.

The same applies to the propane/butane propulsion system. Another factor against the generalized introduction of this type of propulsion is the low output of propane/butane in refineries (about 2 % of the processed crude oil).


Energy source
Processing
processed energy source
propulsion method
mineral oil
water
natural gas
coal
nuclear fuel
refinery
gas works
hydrogenation plant
power plant
petrol
diesel
propane/ butane
hydrogen
natural gas
electr. energy
battery
overhead wire
petrol engine
diesel engine
liquid gas eng
Stirling motor
gas turbine
hydrogen propulsion
natural gas eng.
electric motor
flywheel drive
hybrid propulsion methods

The development of the Stirling engine, however, justifies some hope for the future. Its performance with regard to exhaust gas emission and smooth running is better than the Diesel engine. It can use different substances as working and heating media. A largely exhaust free bus operation is possible with the use of variable thermal regenerators as heating media (energy feeding).

The advantages of the gas turbine for the city bus, i. e.

- low weight
- vibration-free running

are offset by the following disadvantages:

- high fuel consumption (especially were exhaust emission values have been reduced to the levels of Diesel engines and where a major part of bus operation takes place in the lower efficiency range);
- great space requirements (turbine with large air intake and exhaust devices, additional units and heat exchangers).

The factors against the use of steam engines are: high engineering expense and engine weight, as well as fuel consumption. No solution has yet been found to the problems of lubrication in connection with the use of water as working medium, and bad winter performance.

Research and development in the field of hydrogen propulsion are in their early stages. The low energy density of liquified hydrogen and the problems related to fuel storage and transportation (heavy and costly tanks) imply higher costs compared to the Diesel engine. As regards the quality of its exhaust gases (steam and small quantities of nitrogen oxide) the hydrogen engine compares favourably with the electric motor.

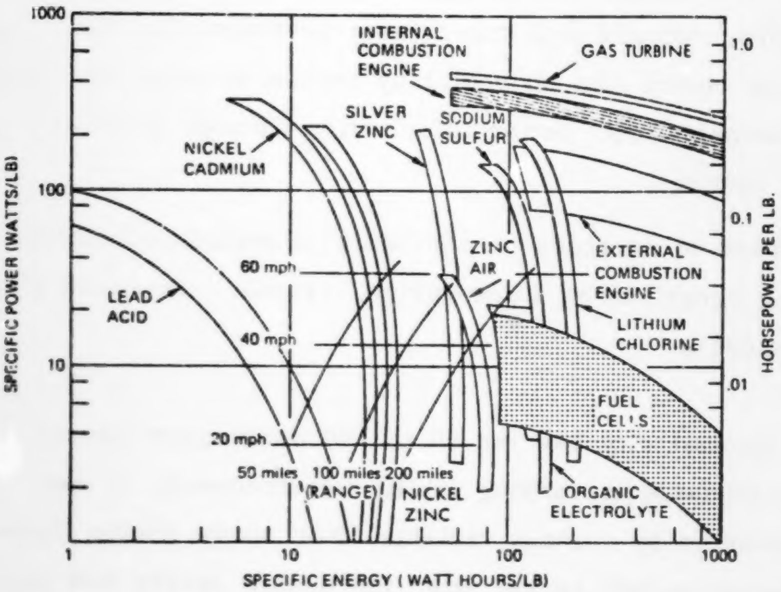
The electric propulsion system operating with a contact line has already been described in connection with trolley buses. Battery-driven electric motors have not yet succeded in making a major breakthrough owing to the low energy density of the usable batteries (e.g. lead - acid battery) which militates against economic operation. For a given number of passengers per bus, the heavy deadweight of the battery may require the addition of a trailer. The proportion of the additional cost involved in the operation of battery-driven buses as compared to Diesel engine buses is being investigated by tests conducted with battery driven buses in the cities of Düsseldorf and Mönchengladbach (FRG). On the other hand, thyristor control and regenerative braking score favourably in the economic consideration.

Vehicles with hybrid propulsion or hybrid energy systems such as an electric propulsion fed by a battery or by a Diesel engine/generator result in lower operating costs compared with the purely battery driven propulsion system, but they suffer from a heavy deadweight of the propulsion unit.

In the present state of development of the fuel cell propulsion system it is difficult to say anything about its possible applications, as only one technically developed low-cost design is so far operational (a cell with potassium hydroxide as electrolyte).

The gyro drive, usually combined with an electric motor, is a system storing and releasing energy from a fly-wheel. However, on account of its limited storage capability, this system can at present only operate within a short range (limitation by centrifugal forces for steel fly-wheels). Although it is possible to increase the storage capacity through higher flywheel speed by using super-flywheels - an improvement already put into practice for stationary operation - major engineering efforts are still necessary in order to absorb the gyroscopic moments caused by the vibrations, pitching and rolling movements of the vehicle.

The below diagram illustrates the relationships between energy density and power density for the various types of propulsion:



Further technical and operational improvements for motor buses are possible through:

- standardisation and rationalisation by vehicle standardisation;
- provision of more convenient stops and stations (installation of at least one simple shelter);
- simplification of the driving task through automatic gears, automatic ticketing (greater proportion of season tickets) and measures easing the flow of traffic (as below);
- installation of bus lanes;
- reduction of traffic obstructions by providing special light signal cycles or preliminary light signals (radio or induction loop actuated) or by legislative measures (e.g. priority for buses pulling out of a stop)
- provision and expansion of communication facilities serving passengers, drivers and supervising personnel (in the operations centre and on route) by means of voice and data radio channels (e.g. better information through automatic position finding).
- organisation of services on the basis of machine-compiled operating programmes (time-tables, vehicle turn-round plans, duty rosters).

Since the normal city bus for 60 to 100 passengers cannot be ideally adjusted to varying traffic requirements, it can be supplemented by certain variants. For heavy traffic there is the one-and-a-half decker bus, the double decker bus and the articulated bus. The one-and-a-half and the double decker buses are primarily used for longer trips. The small city bus is used for lower traffic density, mainly in the inner city areas, even in pedestrian precincts, in rural areas or in the sparsely populated collection areas of rapid transit rail systems.

2.2.2.6 Dial-a-Bus Systems

Since the early 1960s dial-a-bus systems have been operated with small city buses under the following names:

call bus (Anrufbus)
Buxi (Bus-Taxi)
CARS (Computer-Aided Routing System)
DART (Dial-A-Ride Transportation)
Demand-Bus
Demand Responsive Transportation System
Dial-a-Ride (DAR)
Hail-and-Phone Service
Jitney-Bus
Retax (rechnergestützter Taxi-Bus = computer-aided taxi bus)
Subscription Bus.

They are mainly operated as demand-actuated and -responsive bus services. A great variety of trials and tests are being conducted under the above system names. In 1974, between 30 and 40 systems were operated in North America since then 1 or 2 systems have been added each month [12]. While some countries are still in the process of preparing tests (FRG), others have already discontinued some renowned testing programmes (Buxi in the Netherlands, Haddonfield in the USA). Nearly all testing programmes were based on manual dispatching, without computer support. Current tests have only one or two buses in operation. The necessary amount of communication is handled over a certain number of radio channels, with a capacity of 10 to 20 buses per channel (frequency), normally sufficient for 150 taxis [12].

The need for road side telephones and their numbers depend on the density of the telephone network in the area to be served by a dial-a-bus system. After his call, the customer is informed about his waiting time, depending, among other things, on the number of vehicles in operation. In conditions of constant demand, a great number of vehicles in operation will reduce the load factor or vehicle productivity (= number of journey demands per vehicle per day or per hour) while minimizing the number of detours from the direct route (detour factor), i. e. reducing average transit times. There are three types of dial-a-ride journeys: the one-time immediate trip, the deferred journey and the periodically recurrent journey. Waiting time is a factor interesting only in connection with the immediate trip demand, when the passenger wants to be carried immediately, or as early as possible. The deferred trip is the trip which the customer wishes to make at a specific point of time in the future. Periodic trips are carried out regularly at the same time, on the same week days to the same destination.

There are also combinations of demand traffic and fixed-route traffic (line traffic), serving a certain number of fixed stops on each journey. At these stops, "unannounced" passengers can get on the bus from where they are either carried to another fixed stop or direct to their destinations.

Records indicate that in North America [13] the dial-a-ride system

- was positively accepted by the operators and is already covering an important part of short-distance transport;
- has been and is still being set up by a small number of local communities though knowing that its costs cannot be covered from fare revenue.
- does not present any technical difficulties for door-to-door-transport;
- is welcomed by the public
- attracts motorists to using public transport;
- passengers are willing to pay a higher fare.

There is scope for the following developments:

1. Profitability study of the use of dial-a-ride systems in larger areas (possibility of increasing demand over its present level: 4 to 8 pass. per bus per hour).

2. Automated operations control, in particular, automation of the transmission of information; digital communication;

3. Combination of the advantages of dial-a-ride and dual-mode;

4. Adaptation of dial-a-ride to the needs of short-distance goods transport.

2.3 New Short-Distance Transport Systems

New transport systems can be broken down into four main groups:

- track-bound small cabin systems
- track-bound large cabin systems
- track-bound large-capacity systems
- continuous conveyor systems

Leaving out of consideration the continuous conveyor systems suitable for only specific applications (short-distances within the 100 m range), it is obvious that the "self-service taxi on rails" comes closest to meeting the individual needs of passengers; But also journeys in track-bound large-cabin systems give the impression of a more individual mode of transportation than existing means of transport (collective transportation).

Characteristics other than the degree of privacy of transportation serving as comparisons between cabin systems and existing transport systems are vehicle size and applicability for fully automated operation. Further distinctions, in particular between large cabin systems and large-capacity systems, are outlined in Chapter 2.1 above.

2.3.1 Systems and their State of Development

The following chapter is concerned with describing the most important new systems and with briefly indicating the problems involved in the development of individual components. The systems are described in alphabetical order.

2.3.1.1 Small Cabin Systems

The Alden Capsule Transit System, also known as Alden Self Transit or STARRcar, was designed as a 6-seater small cabin offering additional space for standees and prams. The cabins operate on demand and run direct to the desired destination. The vehicles are fitted with vertical rubber wheels for support and horizontal rubber wheels for guidance. The design envisages reinforced concrete structures for the guideway and the lateral walls.

After a series of experiments which Alden Corporation (USA) had conducted already before 1970 on a 300 m test track, the project was stopped. Alden Corp. then participated in the construction and development of a large-cabin system project in Morgantown, under the leadership of Boeing.

The ARAMIS system consists of 4-seater small cabins, with no room for standees and, at least for the time being, no room for prams. By means of electronic detectors, single cabins can be coupled together contact-free to form trains. The cabins will be demand-operated and directly-routed without intermediate stops; they will also operate direct-to-destination scheduled services along fixed routes, i. e. they pick-up "other" passengers. The vehicles are supported on the concrete guideway by four vertical rubber wheels; four horizontal rubber wheels run along vertical metal rails along the sides (serving at the same time as power pick-up) and kinematically control the front axle.

The system was developed by Engins Matra (France); the pilot track consists of a 1 km loop with one off-line station; it has been in operation since 1973 at Orly. In a second experimental phase, started in 1975, the reliability of automatic operation will be tested with 10 to 15 vehicles on a 3 km test track equipped with 3 off-line stations.

The vehicles of the Cabinen Taxi system admit three seated passengers and a pram, but no additional standees. One direction of traffic is operated by the cabins running on the guideway girder, the other direction is served by cabins running below. Cabins cannot be coupled together into larger units. The operating concept provides for demand operated and directly routed traffic without intermediate stops. Vehicle support and guidance are provided by vertical and horizontal solid rubber wheels. The guideway is a steel structure.

The system is a joint development of DEMAG and Messerschmitt-Bölkow-Blohm (Federal Republic of Germany). Since the end of 1974 there is a 1369 m long test track at Wetter-Hagen with one off-line station and one branch-off to the maintenance hall. On this loop, several rail mounted and suspended vehicles are being tested under continuous duty conditions. Since the end of 1975, a more comprehensive test facility, 1.9 km in length with 3 stations, is available for testing of direct routing operation.

The CVS-System (Computer-Controlled Vehicle System) is number four and at the same time the last system which has already reached the stage of extensive testing on major pilot facilities.

The two-to-four passenger carrying cabins of the CVS system are fitted with four rubber-tyred support wheels and centrally mounted guide rollers. A guide arm passing through the slot in the guideway is fitted with two guide rollers which run along guide rails in a hollow box. The front support wheels are steered by the front guide arm whereas the rear guide arm serves as precaution against derailing. The system permits of the coupling together of cabins.

A number of Japanese firms are involved in the project development: Mitsubishi, Hitachi, Tokyo Kogyo, Fujitsu and Nippon Steel. A test track, 4.7 km in length has been in use since March 1974, on which a great number of different vehicles (about 60) have been tested for fully automated traffic flow. The cabins are designed for different speeds; some are equipped with seats only in direction of travel, others with seats only in opposite direction of travel (for safety reasons, allowing higher emergency braking deceleration values = 5 m/s^2); some cabins are exclusively used for testing of goods haulage; others consist only of a chassis. The test facility includes stations, depots, maintenance and repair shops.

However, a great number of concepts of small cabin systems were given up even before a test facility was built. Fairly detailled concepts exist for about 30 different systems. The list on the following page is limited to some developments which must be mentioned in a study concerned with new short-distance transport systems:

System	Sponsoring Agency
Aerial Car Transportation	The John Hopkins University/USA
Aerospace PRT	The Aerospace Corp. /USA
Aeroglide or Aircab	Universität Karlsruhe/FRG
Airmobile	Logan E. Setzer/USA
Automatic Rail Taxi or - Blake Automatic Taxi or - Brush Driverless Taxi or - Cabtrack	Brush Electrical Engineering/GB
Automatische Bahn	Ingenieur-Büro Heidt/FRG
Carmatic	P. G. Zehnel/FRG
Elan Sig	Schweizerische Industriegesellschaft/Switzerland
Fichter Concept or - Veyar or - Scat	D. Fichter/USA
Fussel Transit System	H. M. Fussel/USA
Hamer System	H. J. Hamer/USA
Insta Glide	Linear Air Motors Inc. /USA
Kleinprofilbehälterbahn or - Sesselgleitbahn	B. Schmidt/FRG
Lectravia	LTV Aerospace Corp. /USA
Lockheed Skylift or - Skylift	Lockheed Aircraft Service Co. /USA
MAC - 2 (Major Activity Center)	Stanford Research Institute/USA
Magnocar or - Maxi (Magnetbahn-Taxi)	Fried. Krupp GmbH/FRG
MAN-System	MAN (Maschinenfabrik Augsburg-Nürnberg)/FRG

Midget Subway	E. J. Smith/USA
Pan-Tran	All American Engineering Company/USA
Perc oder Metran Perc	Massachusetts Institute of Technology/USA
Spartaxi	Gothenburg Transit Authority/ Sweden
Self Routing Rail Taxi	Brush Electrical Engineering/GB
Supra-Car	George Haikalis Tri-State Transport/
Telecar or - Teletrans	Pocutel Corp.; Texas and Teletrans Corp.; Farmington/USA
Tran-Seat	Transpallet Inc. /USA

Further discussion of the state of development is limited to the following four systems:

- Alden Self Transit
- ARAMIS
- Cabinen Taxi
- CVS.

A common feature of all systems is the capability for demand-operated and directly-routed transportation, which means that passengers can "call" the vehicles, like a taxi, and travel to the desired station/stop

- alone or with a group of passengers of their choice
- without operationally imposed intermediate stops
- on the shortest possible route, or
- within the shortest possible time.

By the end of 1974, these characteristics of small cabin systems had not yet been technically tested. Experiments to determine the conditions of demand-operated and directly-routed traffic started in 1975 on two test tracks (Cabinen-Taxi and CVS). Since these test facilities are only equipped with three stations each, the tests do not permit any conclusions to be drawn concerning the problems arising in larger networks from

- impact on vehicle flow (backup) at the junction of two or more heavily loaded line sections;
- time losses when branching into heavily loaded line sections;
- waiting times for passengers at peak hours
- empty cabin disposition etc.

The headway control system of ARAMIS is a combination of ultrasonic and infra-red light procedures, responsible for the "electronic" coupling of the vehicles. The headway measuring system controls the distances between cabins, adjusting them to 30 cm, and constantly forms trains between the stations with varying numbers of cabins. Ahead of an off-line station, cabins destined for this station veer off from the cabin convoy, behind the off-line station, departing cabins will join the convoy. The headway measuring system has been under testing since 1973.

The headway control system of the Cabinen Taxi was extensively tested in laboratory experiments on a test loop with several test sledges. Each cabin emits a signal which is then inductively transmitted to a special conductor cable. These high-frequency signals follow a sinus curve and are attenuated by the conductor cable. A receiver in the following-on cabin determines the permissible headway from the sinus amplitude of the received signal. The testing of the headway control system on the test track started in 1975.

CVS uses a synchronous moving block with three separate computer systems as headway control. Two of the three computer systems are each assigned to a specific speed range and route section; the third acts as centre and supervising system for the two others.

All small cabin systems are equipped with passively operating switching systems. They make it possible to operate short vehicle headways. The technical solutions of all systems are satisfactory. With the exception of the CVS System, which has a non-positive guidance system, the positive guidance systems present relatively few problems.

As all support and guidance techniques are using rubber-tyred wheels and rollers, there are no special technical problems in this area. Important aspects in this context are, however, wheel maintenance and tyre replacement.

The electric propulsion systems of developments do not present any major problems either. The linear induction motor propelling the Cabinen Taxi system has reached a satisfactory state of development. It has a lower efficiency than the electric rotary motor but possesses the following advantages:

- low wear (at carbon brushes, no rotating parts) resulting in lower maintenance costs;
- starting and braking are independent of static friction (no requirement for anti-slip and anti-skid devices, less tyre abrasion, greater climbing ability;
- it generates little noise and is insensitive to dirt
- high reliability and long life.

To wind up the chapter on small cabin systems, it is necessary to point out that the most difficult problem of operations control and the problems of passenger self-handling and dispatching need as yet to be solved. With all investigated systems, the development is moving towards the large cabin, which means that the operation will be, as a rule, increasingly less demand-actuated and directly routed.

One System,the Japanese CVS,is being tested to establish the system's utility for goods transport, with appropriate facilities and vehicles.

2.3.1.2 Large Cabin Systems

Under the heading of large cabin systems there is an even greater variety of technical developments and therefore, an even larger number of designed and developed systems.

Some systems are already operational in specific applications, e.g. on airports. The following Chapter does not deal with systems which have never left the drawing boards, they will only be mentioned in a list of systems.

The following systems, listed in alphabetical order, are already in operation or under test:

Airtrans - vehicles run in a U-shaped concrete guideway. They are supported by four rubber wheels and guided by laterally fitted plastic rollers transmitting steering commands. The system is further characterized by an electric rotary motor, active switches and a block signal system.

After several test series conducted by the system developing agency, Vought Aeronautics Co. (USA), the first Airtrains system was set up in 1974 at the Airport of Dallas - Fort Worth. The track is 21 km long, 68 vehicles are in operation (17 for cargo).

The A C T System (Automatically Controlled Transportation) is different from the Airtrains system with respect to the following features: larger vehicles, four laterally fitted, horizontal and foam-filled rubber wheels for lateral guidance, four additional laterally arranged turn-out guide wheels for steering serve the passing of the passive switches; automatic guidance control by means of a wayside conductor.

The Ford Motor Co. (USA) exhibited a test and demonstration facility at Transpo 1972 in Washington, with one vehicle but no switches.

The Dashaveyor system is almost identical with the ACT system. Each axle fitted with 2 support and 4 guide wheels is carried by a bogie. At the active switches, lateral guide rails are extended for forced guidance over spindles.

The Bendix Comp. (USA) had also set up a test track (400 m, 4 switches, 3 stations/stops) and 2 vehicles on the Transpo-premises. [33] indicates that Bendix Company has withdrawn its system from the market.

The Guide-o-Matic Train is similar to the above described large cabin systems. The electric motors are fed by lead storage batteries.

The system was developed by Barret-Electronics (USA) for special applications. It was operational in 1970 at Houston International Airport. In 1972 it was replaced by the Monotrain of Westinghouse Air Brake Corp. (WABCO); see also under Passenger Transfer System.

The H - Bahn is a suspended vehicle system. The vehicle chassis runs in a box girder. Support and guidance are provided by two centrally flanged steel wheels; running stabilisation, especially when running over the passive points, is afforded by horizontal rollers fitted above the steel wheels. The vehicles are driven by a synchronous, or if necessary, also asynchronous linear induction motor. The drive-related headway control system by means of a synchronous linear motor is supplemented by an additional short block signal system.

The system was developed by Siemens and Düwag (Federal Republic of Germany). Tests have been carried out since 1974 on a 150 m test track with one vehicle. A large-scale test facility will be constructed in early 1976.

The Jetrail system is a monorail suspension system, with 8 ebonite tyred wheels running along the lower part, i. e. the web of a I-girder. The vehicles are driven by electric motors. The system, developed by Stanray Corp. Jetrail Div. (USA) has been in operation since 1970 at the Airport Dallas Love Field. The system is no longer in use since Braniff International Airlines for which it served as a feeder system has moved its scheduled services to the new airport at Dallas/Fort Worth. Guideway installations and one vehicle are used for research purposes by PRT Systems Inc.

The Morgantown PRT was developed from the Alden Self and the STARRcar System. But its components and functioning also show some similarity with the Airtrans system.

The name of the system is derived from the place in which the system was built up. In 1975 the system was put into operation with 45 vehicles running on a 3. 6 km track with switches and 3 stations. No decision has as yet been taken about further extension of the system. Operation with revenue passengers was started in September 1975. The project leading agency is Boeing Co. (USA).

The Passenger Transfer System is part of a group of systems, known under the names Wabco Peoplemover and Monorail. The vehicles are supported by vertical rubber wheels and guided by horizontal rollers running along the vertical web in the middle of the guideway.

The Westinghouse Air Brake Co. (USA) has a pilot facility at Cape May, N.J. In 1973 the development was taken over by Rohr Ind. Inc.. Wabco models J, K, M, N and Q were constructed as proto-types. Model P, a three-unit articulated train is in operation at Houston International Airport.

The vehicles of Poma 2000 run on rubber wheels over a steel guideway and are guided by rollers running along two laterally fitted steel webs. The vehicles are attached to a hauling rope running in the middle of the guideway. When approaching a station, the vehicle detaches itself from the hauling rope and is decelerated by a number of fixed wheels driven at different speeds (when leaving the station, acceleration is effected analogously).

The developing companies CREUSOT-LOIRE and Pomagalski (France) have set up a 600 m long test track with three vehicles at Grenoble. For 1975/76 its is planned to extend the test facility by adding a second station and three vehicles.

The Rohr Monocab system consists of suspended vehicles whose pneumatic tyred chassis runs in a box girder, (vertical support and horizontal guide wheels). Steering wheels outside the box girder facilitate the passing of the passive points.

Monocab Inc. (USA), a subsidiary of Rohr Ind. Inc., exhibited a 400 m demonstration track equipped with switches and vehicles at Transpo 72. At Chula Vista, California, Rohr Ind. Inc. built a 150 m long test track for a more advanced vehicle with magnetic suspension.

Also the Romag system was developed by Rohr Ind. Inc., and presented at Transpo 72, but only on an 18 m long guideway. The rail mounted vehicle is equipped with four unilateral linear induction motors for drive, support and guidance.

The further development of Transurban Takt, a project designed by Krauss-Maffei (Federal Republic of Germany) was suspended. The main characteristics of the system were LIM drive and an electro-magnetic support- and guidance system. The promoters set up costly tracks and built several test vehicles. Reasons for the discontinuation of the project were difficulties in connection with the passing of switches, negotiation of narrow radii, the high empty weight of the vehicles, and high energy consumption by the electromagnetic support and guidance systems (uneconomic operation).

The main distinctive features of the TTI-OTIS system are the air-cushion vehicles. Guidance is effected by horizontal rubber wheels running in a U-shaped concrete guideway. Approach to stops is planned to be at right angles to the normal direction of travel in a special stopping track. The vehicles are driven by a unilateral LIM and an aluminium reaction rail in the middle of the guideway.

Ascinter-Otis in France offered the system under the name Transtech-TTI.

The system promoters Transportation Technology Inc. and Otis Elevator Comp. (USA), exhibited some vehicles on a demonstration facility at Transpo 72. An alternative solution consisting of vehicles with rubber wheel chassis and an electric rotary motor is being studied.

The VEC system is a cross-breed of a cabin system and a continuous conveyor system. In addition to the original version consisting of two passenger seats in an open cabin, there is now also a second version with a closed cabin for 4 to 6 seats and 6 standing passengers. The cabins are supported by a plain coil chain moving along at constant speed. When approaching a station, the vehicle is detached from the chain and decelerated by a wheel.

The system developed by SAVEC (France) and Cytec Development Inc. (USA) was tested in 1972 on a 170 m long pilot track including stations at La Défense (Paris) under true operating conditions with passengers. At present it is being operated as a link between a department store and a car park building near Paris-Montparnasse.

The VONA system (Vehicles of New Age) is characterized by the following features: the vehicles are supported by rubber wheels which run over two lateral guideway girders, and guided by a centre guideway beam. The smallest unit consists of two coupled vehicles. The switches are active. The developing agencies Mitsui & Co. Ltd. and Nippon Shargo Seizo Kaisha Ltd. (Japan) operate an ambitious testing and demonstration facility in the Yazu amusement park at Tokyo.

In addition to the above mentioned systems which do not necessarily promise further development, the following other large-cabin concepts are known (for the systems marked with an x), small test facilities are available):

System	Developing agency
Articulated Train	Articulated Train Systems/USA
Beltica x)	Toshiba Electric Co./Japan
Carveyor	Goodyear Tire & Rubber Co/USA
Compactbahn	Werner Müller/Switzerland
Comprehensive Transit System	De Leuw, Cather and Partners/GB
Davino System	A. Davino/USA
Double Magna Car	? /FRG
Flyda	? /GB
Goodell-Monorail	Goodell Monorail Systems Inc./USA
Greene Monorail System	? /GB
Gyrocar	Sommers/USA
Habegger Minirail (Typ III)	Habegger AG/Switzerland
KGV x)	Kawasaki, Fuji/Japan
KRT (Kobe Rapid Transit)	Kobe Steel/Japan
Kompaktbahn	Fr. Krupp and Krauss-Maffei AG/FRG
MAT x)	Mitsubishi Heavy Industries/Japan
Mini-Monorail	Toshiba Anzen Sahudo/Japan
Minitram or	EASAMS/GB
- Slim (single-sided linear induction motor)-wheel	Hawker Siddeley Dynamics/GB
Minitube or	SNCF und R. Geais/France
- Mini-Metro	
Monobeam Scherer	Scherer Monobeam Co/USA
NET - 1, 2, 3	Stanford Research Institute/USA

NTS	Niigata Tekko, Sumitomo/Japan
Orbit or - TAAT or - Navicelle	Schindler und A. Thaon/Switzerland
Overground	B. Richards/GB
Paratran x)	Hitachi Tokyo, Shargo/Japan
Pitkanen System	Westwood Research Inc. /USA
PSS/LST (Pkw-Schnellbahn-System/Leichtschienentaxi)	T. Romahn/FRG
Rail Car Transit System	Northwestern University
Sky-Kar-Transivator	Sky-Kar Corp. /USA
Train Vertébré	A. Goicoechea/Spain and Brissoneau et Lotz/France
Transcab or - Transdhec or - Transveyor	Battelle Inst. /Switzerland
Uniflo PRT	Uniflo System Comp. /USA
Unitran	Unitran Monorail/USA
Zworykin TACV	Zworykin, RCA Corp. /USA

For large-cabin systems, efficiency is as much of a problem as for small cabin systems. The larger cabins have of course, a higher carrying capacity, but on the other hand, the presence of standees imposes lower acceleration and deceleration values. This means that braking distances and minimum vehicle headways have to be longer.

In the interest of a higher line capacity, most of the technical concepts are based on passive switching and off-line stations. Because of the low carrying capacity of the cabins, the operating concepts in most cases provide for demand actuation and destination coding. If only certain stations of a fixed route can be pre-selected as destinations, the system corresponds in principle to the concept of a horizontal elevator, mainly operated in the form of a shuttle or loop service.

However, the problems involved in free pre-selection and coding of destination in a larger network, are much more complex and have never been put to test. In any case, some difficulties have already been experienced on the relatively small "network" of the Airtrans-System at Dallas/Fort Worth with its 55 stations.

For most large-cabin systems headway control is performed by an extensively tested traveling block system (continuous signalling system).

With respect to the support and guidance techniques, it is evident that the majority of the systems in experimental stage, and all systems already in operation, are supported by chassis fitted with rubber-tyred wheels. Contact-free support and guidance techniques involve certain disadvantages for short-distance transport systems because of their high energy consumption. This fact has so far prevented their operational use or has even resulted in a suspension of their further development (e. g. Transurban Takt System).

Most large cabin systems are designed for electric drive by rotary motors, or by linear induction motors of different types. As regards linear induction motors, the observations made in the Chapter on small cabin systems similarly apply. Other possible propulsion methods for large-cabin systems are:

- continuous carrier equipment such as hauling ropes or articulated chains,
- air fans (air nozzles in the guideway).

Like the linear induction motor, these drive systems still call for substantial testing and experimenting as well as further development.

2.3.1.3 Other Rail Systems (Large-Capacity Vehicles)

The outstanding characteristic of large-capacity systems is the carrying capacity of its vehicles; the operating concept is normally based on scheduled operation along fixed routes and stops at on-line stations. Some large-capacity systems are already operational in specific applications, others are in the process of experimentation on testing grounds or still in the design stage. The operational group includes the following systems, listed in alphabetical order:

The Aerobus is suspended on rubber-coated wheels from two parallel guideway cables. It can only operate in special applications lacking any concept of a switching system. The guideway cables are fixed to the supporting cables so that only under loading conditions the latter form a horizontal guideway. Changes in overall vehicle weights or train formation necessitate alterations of the guideway.

Since the beginning of 1975 such a system is operating on a 3 km long track at the Federal Garden Show in Mannheim, (FRG) comprising of vehicles with 18 wheels, 100 seats and d. c. motors. System manufacturer is Aerobus Engineering Ltd. G. Müller (Switzerland). One variant of the above described system is the London Aerial Tramway System.

The vehicles of the Aerotrain Suburbain are supported and guided by air cushion.
They are driven by a voltage and frequency controlled double-sided linear induction motor whose aluminium reaction rail sits vertically on the concrete guideway.

Originally it was planned to start the construction of a sub-urban link between La Défense, Paris and Cergy in July 1973, according to the system designed by the Société de l'Aérotrain (France). For cost reasons, the system was abandoned for a conventional rail system. The company still runs a pilot track with one prototype vehicle.

The Alweg-Monorail or Alweg-Bahn is similar to the Habegger Minirail of which types 1 and 2 (for exhibition ground applications) are already in operation at various places. The vehicle chassis straddles a concrete girder.

Monorail systems of the Alweg design are operational as short distance airport links between Tokyo and Haneda Airport, at Aicha and at Kanagawa (Japan) and at Seattle, and on exhibition grounds at Disneyland Anaheim and Disney World Florida (USA). The pilot plant in Cologne (Federal Republic of Germany) is no longer in operation, and the monorail system at the Turin exhibition ground has already been dismantled.

The Safège system, also known as Safège Monorail or Métro Aérien Safège, is a suspension system. The bogies fitted with four rubber wheels for support and four for guidance run in a guideway girder which is slotted on the lower side. The switches are active, headway control is performed by a block system, vehicles are driven by d.c. motors. The first track in operation was the 7.5 km link in Shonan (Japan), it has been working since 1971.

The Transit Expressway (also known as Skybus or Passenger Shuttle or Satellite Transit) runs on rubber support wheels. Guidance is effected by horizontal rubber wheels moving along the web of the I-shaped girder and acting on the steering axles. Further system features are: active switches, continuous signalling system for headway control and d.c. motor drive.

Guideway design and several vehicles have been tested since 1965 on a 3.2 km test track. In a second development stage, the system manufacturer, Westinghouse Electric Corp. (USA) made considerable design alterations in vehicles and track, in order to achieve satisfactory switching behaviour. With only a few minor modifications, the system was set up as a horizontal elevator at the airports in Tampa and Miami /Florida and Seattle-Tacoma/Washington, and at Busch Garden /Williamsburg.

The Tridim system has air-cushion supported vehicles. Drive and guidance functions are performed by elastically supported pinions on a rack, horizontally fitted to a rail running in the middle of the guideway. Vehicles are either driven by an electric rotary motor via the pinion or by a linear induction motor.

In 1973 a small test vehicle for 6 passengers was tested on a 300 m experimental track by the developing agency Société de l'Aérotrain (France).

Like the Alweg-Bahn, the Urba system has been known for some time already. The suspended vehicles and their chassis are supported and guided by suction in a box girder slotted on the lower side. The sub-pressure is generated by fans in the bogies. The use of linear induction motors for propulsion is envisaged.

Seturba (France) a group of developing firms have been testing the system since 1970 on an 80 m track near Lyon.

The vehicles of the VAL system (named after Villeneuve d'Ascq - Lille or véhicules automatiques lêgers) are rubber-tyred. According to the original conception four vertical support wheels run on the concrete guideway, eight horizontal guide wheels run along lateral steel rails. Other system features are: side conductor rail and d.c. motor, active switches, headway control determined by time intervals.

The system was developed by Professor Gabbilard and the Société Engins Matra (France). There has been since 1973 a 1.6 km test track fitted with switches and vehicles, near Lille-Est.

In the meantime also an articulated vehicle with 44 seats and 116 standing places has been put into service. Additionally two steel rails habe been fixed in the middle of the track. A vertical mounted steel wheel is guided through this slot. A movable switch blade guides the two steel wheels belonging to each bogie into the wanted direction.

In accordance with the procedure followed for small and large cabin systems, the following list contains the names of further concepts for large-capacity systems:

System	Developing Agency
Air Rail Transit	Ideonics Corp. /USA
A. Hawes Monorail	Universal Design Inc. Alan Hawes/USA
AT 2000	Société Automatisme et Technique/ France
Automatic Bus (or Synchrobus)	SERI-Renault Engineering/France
Bingham System	Bingham Assoc. /USA
Bi-Span-Transit	L. L. Davis/USA
Catenerail	Bureau Central d'Etudes des Problèmes de Transport et Parking Urbain/France
Clair Rapid Transit	W. J. Clair/USA
Fast Transit Link FTL 1	Stanford Research Institute/USA
Fogel Personal Express	L. Fogel; General Dynamics/USA
Gravity-Vacuum Transit Mark 3B	Tube Transit Corp. /USA
Gyro-Glide	Northrup Corp. /USA
Hyperbus	R. A. T. P. /France
Kearney High Speed Railway	J. C. Kearney Co. /USA
Leitschienenbahn or	Kuch/FRG
- Guiderail System	Jacobi/USA
Lockheed Monorail	Lockheed Aircraft Co/USA
Magnetische U-Bahn (Museb)	MAN/FRG
M (Mehrphasen)-Bahn	M. Lindner/FRG
Mono-Tri-Rail	Mono-Tri-Rail System/USA
Pneumatic Tube System	Hickmann/USA
Rotocar-Monorail	North American Monorail Corp. /USA

Geats (Lizenz Safège)	General Electric Co/USA
Sky Line	Moskowski/USA
Swish (like Aerial Transit System)	Aerial Transit Systems Inc. /USA
Téléférique Automoteur	Neyrpic (Alsthom)/France
Terrafoil	B. J. Hartz/USA
Tubeway	J. Allen/GB

Modern track-bound large-capacity systems are in many ways similar to existing rapid transit railway systems. Some of the systems are designed for man-operation, most of them for scheduled operation along fixed routes and fixed stops at on-line stations. The differences lie therefore in modern support and guidance techniques, new headway control systems or smaller vehicles. Inevitably, the dividing line between new-type and conventional systems will be as arbitrary as the one separating large-cabin systems from large-capacity systems.

Looking at the Wuppertal Schwebebahn (suspended railway in Wuppertal/FRG) or the tracked cable car system in San Francisco, there can be no doubt that these systems are as unconventional as many of the new developments or concepts. Both systems are just a "little" older than the relatively modern Alweg system.

The BART System in San Francisco, the proposed concepts for the Pullmann-System and the HHA-Paternoster System (each characterized by single demand-operated rapid transit vehicles) could be considered as further developments of existing rapid transit railways or as new concepts.

Nearly all modern track-guided large-capacity systems are designed for automatic train operation. One approved and often used method is the continuous signalling system. Usually the switching system is active, which is sufficient for the proposed operating concept, based on vehicle frequencies of more than one minute.

In a great number of cases the support and guidance systems are equipped with "fairly unconventional" rubber-tyred chassis. With a few exceptions, the vehicles are electrically driven by d.c. motors fed over a contact rail.

2.3.2 Operating and Traffic Experience

Although many new short-distance transport systems have reached a high level of development, not a single one - leaving aside a few projects for specific applications (i.e. airports, exhibition grounds) - has made a major breakthrough. This may be attributed primarily to the operating and overall costs of the systems and less to their technical state of efficiency. One of the most spectacular examples is the building freeze imposed on the Morgantown project because the future operator refused to take over the foreseeable high operating costs.

In order to avoid the unpleasant incidents experienced with rubber-tyred vehicles by the Airtrans System (system failure in conditions of ice and snow) it may be expedient to either heat or encase all surface-level or elevated guideway sections, as already done for the Japanese rapid transit system at

Sapporo. Although system designers and manufacturers do not normally envisage - or only in certain circumstances - heating of the system, these cost items should be included in the calculation of operating and capital service costs. At Morgantown, the guideway is heated by means of hot water and glycol, although the installation of electrical heating wires would have been cheaper.

Experience with the operating concepts of small and large cabin systems is limited to the knowledge that the concept of the horizontal elevator system is applicable without any problems in a limited network. The Airtrans System is one example for this concept. However, what little operating and traffic experience there is, is not necessarily representative. Out of a total network length of 20.6 km, only 4 km are not underground; passenger and goods are carried in different vehicles; airport personnel are using separate cabins from those used by the airport users; moreover, the system users at the airport constitute a different group of travelers from the one generally using public transport. Therefore, experience with regard to vandalism in this particular application is certainly not representative for and applicable to automated systems in general. This restriction also applies to experience with vehicle load factors and system acceptance; it cannot be generalized because this system application is determined by specific transport demands in a limited network and by a special group of system users. On the other hand, experience gained with maintenance and repair of Airtrans vehicles and installations can be utilized, on the understanding that the special conditions of any new vehicle or system in operation will have to be duly taken into account (i.e. increased requirement for maintenance and servicing). According to [33] the personnel requirements of some of these systems compare as follows:

- the Airport Shuttle System at Tampa/Florida	0.75 employees per vehicle
- the Airtrans System at Dallas/Fort Worth	2.6 employees per vehicle
- the PATCO rapid transit system at New Jersey	3.7 employees per vehicle

As the vehicles of the above systems differ in size, a comparison of personnel requirements is only meaningful if related to passenger-kms. On this basis, the Airtrans-System has the most unfavourable score.

The operating experiences with simple shuttle or loop services are even less representative. It is known that the Wabco System has had no accidents since its inauguration in 1968. On the other hand, the low running speed of its vehicles ($v = 20$ km/h) would not meet the requirements of a public short-distance transport system.

Systems set up on exhibition grounds serve a much more representative community of users but also in a limited application. The VONA large cabin is similar to many other rubber-tyred vehicles of new transport systems but has been known to show unsatisfactory running behaviour [21].

An incident occurred when due to a defect, an Aerobus suspended vehicle got stuck between two stations. The occupants of the vehicle had to be roped down. There are a number of proposed solutions for the rescuing of passengers from suspension systems. However none of these compares favourably with the advantages of an emergency excapeway provided by rail mounted systems. Further rescue methods might consist of:

- rescue by means of ladder trucks e.g. of the fire brigade (requirement: the guideway must be accessible from all sides)
- provision of special system-related rescue vehicles (worthwhile only in connection with off-line stations)
- rescue from "opposite track" by means of a slidable bridge;
- lowering of the entire vehicle by means of a device that can be operated by the occupants from within the cabin;
- possibility of climbing over a ladder on the upper side of the girder;
- lowering of an elastic rescue hose serving as a slide.

The problems of passenger rescue take on particular significance when considering the great number of vehicles in operation in a small cabin suspension system. As public transport systems also carry children, old and handicapped people some of the above mentioned rescue methods have to be ruled out as impraticable. Time is a very critical factor with all rescue arrangements based on assistance from operating personnel; until the arrival of the rescue party, passengers must be protected against falling out due to opening of doors and windows as well as against fire outside or within the cabin. Rescue experience for the various configurations of small cabin systems (supported, suspended or straddling) is not available. Manufacturers are still experimenting with different alternatives on their testing facilities.

Small cabin systems cannot be expected to be as readily accepted by the traveling public as "out of the ordinary" large-cabin or large-capacity systems using conventional techniques. One inherent characteristic of small cabin systems is their possible effect on the psychological or physical condition of the passengers, manifesting itself in:

- a general reluctance against automatic operation (phobia, lack of self-confidence)
- hesitation to take on an increasing number of functions (exclusive requirement for self-information - no assistance from personnel, ticket-vending machines, calling of cabin, selection of destination, vehicle dispatch)
- emotional reservations against driving on top of or under a guideway girder (atop riding or suspended cabins)
- critical approach to riding at short headways and to the vehicle configuration (e.g. no nose, only a window pane = Cabinen Taxi; no outlook in front = Aramis; seats arranged in opposite direction of travel = CVS)
- fear, especially among female passengers, of harassment (forced rides with unpleasant passengers cannot be avoided).

As long as small cabin systems are not tested in operating and traffic conditions, passenger inquiries on the acceptance of such systems must be handled with caution. An inquiry among public transport users in Hamburg [4] produced the following results:

- 90 % of the responders consider it an advantage of conventional systems that the degree of passenger involvement in the system's operation and handling is fairly low;
- 84 % are in favour of systems using operating personnel;
- 61 % consider direct-to-destination travel as an important or very important feature;
- 57 % prefer to travel more or less alone or only in the company of friends or family members;
- 29 % have expressed reluctance against riding on or under a guideway girder.

Forecasts on the load factors of small cabins can only be made on the basis of the experience available for private transport carried out with the automobile, which denotes an average load factor per cabin of 1.3 to 1.4 passengers. A simulation of these figures [22] has shown that about 40 % of all kms run by the vehicles would be empty runs. With conventional systems 10 to 15 % of all vehicle-kms are empty runs.

On the other hand the purely physical integration into the urban pattern and coverage of the prevailing transport demand are factors which can be appreciated even in the absence of actual experience. By and large, large-capacity vehicles show the same advantages and disadvantages as conventional systems. There have been concepts for axial layout of large-capacity rapid transit networks with a view to encouraging development along the radial axes of the system and thus to improving its development effect and area coverage. The zoning patterns resulting from these concepts, however, do not coincide with the prevailing preference for one and two-storey houses in residential areas. Moreover, it frequently happened, on account of the high land prices that high-density developments did not take place along the axes of rapid transit networks but - contrary to the expectations - in the triangles formed by its radial axes, because of the availability of the land necessary for such developments at favourable prices.

Cabin systems are expected to produce better coverage of and adaptation to the prevailing building pattern. The question of integration into and assimilation with the urban structure is therefore significant, bearing in mind that better traffic coverage involves greater density of network and stations. With a network essentially composed of elevated guideways, greater network density is tantamount to more physical structures. In communities with narrow streets (less than 20 m in width), rectangular road junctions and only few rounded block corners it will, however, be fairly difficult to integrate a new system with off-line stations, especially if it is elevated.

In addition to the space requirements, elevated systems must also be considered under functional and aesthetic aspects. Changes in the use of buildings and houses might be an unanticipated consequence of cabins passing at the level of the first or second floors thus affecting their quality as living quarters and the lighting conditions of the ground floor rooms. Commercial use of the upper floors on the other hand might be of advantage because they provide more direct access to the stations.

Finally, consideration must be given to the economic aspects in so far as they are connected with coverage of transport demand. Near rapid transit railway stations, cabin systems are intended to compete with buses when these act as feeders and distributors of traffic; but they are more dependent than these on a minimum amount of traffic, for economic reasons.

The determinant cost items are capital costs, and also maintenance and servicing costs. They cannot be offset by certain advantages in the field of operating costs (reduction in personnel costs).

For feeder and distributing functions to and from rapid transit lines, large-cabin systems are superior to small cabin systems for the following reasons:

- the small cabin system's chief superiority lies in its greater responsiveness to rider demand.
- the merits of direct-to-destination travel capability are not felt (there are only few intermediate stops on the feeder line and transfer to the main line is inevitable).
- on the usually short distance there is no point in providing private riding atmosphere and garanteed seats.

- it is unlikely that small cabins would change the modal split or the mobility patterns.
- the costs of a denser network (off-line stations, a great number of cabins, idle during off-peak hours, and more sophisticated control and surveillance techniques) would rise disproportionately compared with the increase in the system's overall benefits.

3 Assessment and Comparison

3.1 Assessment Approaches

3.1.1 Characterization of Possible Methods

3.1.1.1 Requirements for an Assessment Method

Assessments and comparisons are conducted to make possible well-grounded decisions for or against the introduction, development, promotion etc. of transportation systems. In doing this, 4 major aspects have to be taken into account:

1) Transportation systems encompass a multitude of technological and organisational components (construction of drive unit, guideway, but also method of passenger handling etc.) whose very interdependence and interplay make up the special characteristics of a transportation system. Therefore, characterization and assessment of a transportation system by means of a single (one-dimensional) criterion (e.g. cost of system per passenger-km) is not sufficient.

   The assessment method to be applied must, therefore, be of a multi-dimensional nature to cope with the complexity of transportation system.

2) The decision for or against a certain transportation system produces effects which impinge on other sectors, too (e.g. the general public which does not use a system but has to tolerate its existence). Furthermore, many effects are not direct but, rather, consequent (higher-order) effects.

   The assessment method to be applied must, therefore, be able to take into consideration effects of the first, second, ... n-th order to account for the comprehensive nature of the transportation system.

3) The decision for or against a transportation system is always made under uncertainty, i.e. with incomplete knowledge of future development.
Especially with decisions of great import, like the introduction of a transportation system, it is necessary for decision-making and allocation of resources that the decision-maker applies his own concepts and assumptions to cope with this uncertainty and clearly understands his own assumptions and their consequences.

The assessment method to be applied, therefore, must make clear at which points in the assessment process subjective valuations are required and what their consequences will be. Furthermore, it must be able to take in and apply such valuations consistently.

4) Especially because of economic considerations, transportation systems are usually designed only for certain tasks. The assessment method to be applied must be able to account for these specialisations.

Firstly, it must make possible the definition of tasks and the assignment of systems to these tasks. Secondly, within these assignments, it must provide for equal treatment of the systems investigated, to make possible a consistent inter-systems evaluation. Thirdly, it must provide for a comprehensive assessment of systems which are able to fulfill several of the defined tasks (cf.[14], p. 9 and 15 et seq.).

3.1.1.2 Existing Assessment Concepts

The concepts able to fulfill the requirements specified above are designated by several names (cf.[23], [25], [24], p.21). Common features of all concepts are:

- a set of complex alternatives which have to be assessed with regard to
- a multi-dimensional system of objectives
- in accordance with the preferences of the decision-maker and should be
- set out according to their preferability; the order should correspond to the "values" of the alternatives as determined by the method applied.

The "values" of the alternatives are, by their nature, indexes of the order of their preferability and are valid only within the context of the circumstances and limitations of the decision-situation and the decision-assumptions. Only if all effects generated by an alternative are uniformly expressed by an empirically formulated as well as inter-subjectively testable and acceptable unit of reference will the "values" of the alternatives have a corresponding dimension. In this instance, the differences of "values" - in contrast to distinctions between indexes of order - have an empirical meaning too (e.g. as different amounts of required funds or attainable revenue from different projects).

The assessment methods differ in the way and degree to which they use empirical units of reference.

In Cost-Benefit-Analyses (CBA), all effects an alternative generates are expressed in monetary units. If positive effects predominate, an alternative shows a monetary "benefit", and v.v. The order of alternatives is one-dimensional (monetary units) and usually unique. The ratio of "benefit" to resources consumed represents the gradation of preferability.

In Cost-Effectiveness-Analyses (CEA), effects which can be attributed directly to monetary transactions (e.g. costs of operation and construction, revenue from passengers) are expressed in the (empirical) monetary unit. Effects which cannot be directly attributed to monetary transactions are expressed in technical or physical units of reference. They are then transformed by means valuation functions. The order of alternatives is at least two-dimensional (costs/revenue and effectiveness) and usually not unique, alternatives with high costs usually also have a high effectiveness and vv. In some situations it may be possible to generate an order by defining restraints on cost and/or effectiveness. A further possibility is given if the decision-maker is willing and able to define monetary constants for the transformation of effectiveness into monetary units in view of the CEA results. This would, however, transcend the borders of CEA (cf.[24] p. 67, 68).

In Multi-Attribute Utility Analyses (MAUA), all effects are uniformly expressed in units of reference which may be called "systems-utility" to distinguish them from monetary "benefits" and "costs" as in CBA and monetary costs/proceeds and effectiveness, as in CEA. The concept is nearly a mirror-image of CBA. The order of alternatives is one-dimensional (units of systems-utility) and usually unique, and the differences in systems-utility can be interpreted as a gradation of preferability.

The problem of this method is that systems-utility is not an empirical unit of reference as defined above because it incorporates the subjective valuation assumptions of the decision-maker even for effects directly attributable to monetary transactions. Therefore, the requirement of inter-subjective acceptance will, as a rule, not be fulfilled.

The disadvantage of MAUA as compared to CBA is, however, not substantial. Even propagators of CBA will not deny that some effects of alternatives cannot be monetarized, or only under heroic assumptions. The evaluation of such effects is then incorporated implicitly in the constants of monetarization and is also determined by subjective reasoning. In contrast, MAUA openly displays these assumptions.

On the other hand - compared with CEA - MAUA requires an additional valuation of those effects that are directly attributable to monetary transactions. This is no problem as long as the necessary transformation functions can be defined at the beginning of the study. If, however, the monetary effects, esp. the costs, turn out to be highly important to the assessment, for internal or external (e.g. political) reasons, then another evaluation run is necessary.

3.1.1.3 Basic Pattern of an Assessment

Although the methods differ conceptually as described above, there is a common basic pattern which is largely unaffected by methodical particularities

Following ([23] pp. 296 - 302 and [25] pp. 59, 87), this basic pattern of an assessment can be represented in the following way:

1 DEFINITION OF PROBLEM

usually based on a "state-of-the-art" analysis or stock-taking of potential alternatives

2 DEFINITION OF VALUE SYSTEM

2.1 SYSTEM OF OBJECTIVES

- gathering of objectives
- deriving of partial objectives than can be given a concrete meaning and content
- operationalising of partial objectives through (measureable) criteria, principle of strongest possible manner of scaling

2.2 PREFERENCE STRUCTURE

- weighting of objectives
- defining the valuation functions for transforming the attributes of systems with regard to the selected criteria into utilities of the attributes for the objectives incorporated.

3 DEFINITION OF OBJECT SYSTEM (ALTERNATIVES TO BE ASSESSED)

3.1 DECISION ENVIRONMENT

- determining the given environment phenomena which forcibly diminish or restrain the freedom of decision

3.2 PRESELECTION

- eliminating those alternatives from 1 which are obviously incompatible with 2 and 3.1

3.3 ANALYSIS OF ALTERNATIVES

- cataloguing and describing of decision-relevant attributes of the remaining alternatives in the context of the criteria from 2.1

4 EVALUATION OF ALTERNATIVES

4.1 VALUES OF OBJECTIVES

- transforming the attributes into utilities of these attributes by means of the valuation functions from 2.2

4.2 VALUES OF ALTERNATIVES

- amalgamating the utilities of the attributes from 4.1 into a value of an alternative by means of the weights of the objectives from 2.1; the inter-temporal comparability of utilities and thereby of values of alternatives has to be provided for.

5 TESTING OF RESULTS

5.1 SENSITIVITY

- determining of input data for which, because of incomplete knowledge, assumptions had to be supplied. (The incomplete knowledge results from the complexity of the situation to be assessed at the time of decision).

- chosing different assumptions for this data and working out the results following therefrom (regarding the point of time of decision).

5.2 TEMPORAL STABILITY

- determining the input data which can be expected to vary over time; these may be data for which complete knowledge is available at the time of decision as well as those from 5.1.
- chosing of (alternative) assumptions about the development of data over time (e.g. extrapolation of trends, estimation thereof) and working out of the results following therefrom (regarding the time interval).

6 ASSESSMENT OF ALTERNATIVES

6.1 COMPARISON OF VALUES OF ALTERNATIVES

- ordering according to preferability as regards the results from 4.2

6.2 ADDITIONAL ASPECTS

- incorporating the results from 5.1 and 5.2
- incorporating effects which could not be evaluated, by the method in question, but are to be included in the assessment; especially components of the decision environment (3.1) which were not recognized as being critical at the time of preselection.

6.3 DECISION BASIS

- subjectively amalgamating the results from 6.1 and 6.2 to derive an order of alternatives on which the final decision will be based.

Any assessment procedure has to be tailored to the concrete problem under investigation. Even within the same method there are as many assessment procedures as there are problems to be assessed. A "cook-book" about the assessment of complex alternatives cannot be given.

The results of an investigation are valid only within the context of the given decision environment and the valuation assumptions of the decision-maker. A generalisation of results is not permitted. A certain safe-guarding of results is obtained by the testing of results in step 5 of the assessment process. Statements going beyond the results found in step 5 are not covered by the investigation.

A significant problem is that sometimes the decision-maker does not disclose his value system, so that the analysts have to supply assumptions to derive any results at all, or that, because of the complexity and feed-back of the procedure, analysts implicitly supply assumptions of which the decision-maker does not become aware.

3.1.2 Comparative Representation of Methods

3.1.2.1 Assessment Process

The assessment processes (not procedures) of CBA, CEA and MAUA show deviations from the basic pattern made necessary by each assessment concept. The major deviations of each process are represented below. Where stepsof the basic pattern are not described in detail the remarks in the basic pattern obtain.

Cost-Benefit-Analysis

The distinguisting characteristic of CBA is the monetarization of positive and negative effects. This generates the following deviations from the basic pattern.

- operationalising of partial objectives by monetary criteria; effects which cannot be monetarized are described verbally (step 2.1)
- defining conversion constants for monetary criteria (step 2.2)
- determination of the attributes of monetary criteria and description of the attributes for criteria described verbally (step 3.3)
- one-dimensional cardinal order of the values from 4.2; maximisation of benefit-cost ratio (step 6.1)

Special problem: Opposed to monetary costs and benefits are effects which are only verbally described and listed according to their significance (not weighting factor) and can only be ordered in a corresponding sequence. An amalgamation within the model is therefore impossible because in that case the effects would haven been monetarisable. (step 6.3)

Multi-Attribute Utility Analysis

In MAUA every effect is converted into units of systems-utility by suitable transformation functions, and an assessment of alternatives can be derived consistently.
Systems-utility is, however, a non-empirical unit of reference. The deviations from the basic pattern are as follows.

- weighting criteria and defining of transformation functions, even for monetary criteria (step 2.2)
- multiplication of attributes and weights (= partial utilities) and summation of partial utilities (= systems-utility of the alternative) (step 4.2)
- one-dimensional order of values from 4.2, maximisation of systems-utility (step 6.1)

Cost-Effectiveness-Analysis

CEA leaves effects directly attributable to monetary transactions in this dimension and determines partial utilities for non-monetary effects which are then amalgamated to form the effectiveness. The cost and effectiveness of every alternative are disclosed separately.

If the decision-maker desires a one-dimensional order of alternatives he must define transformation functions and weights for the determined cost or effectiveness to either determine monetary costs/benefits (monetarising of effectiveness) or systems-utilities (utilisation of costs). The decision-maker is, however, able to wait for investigation results, and he may afterwards, knowing the monetary and effectiveness values, determine the necessary functions and weights. The deviations from the basic pattern are as follows:

- weighting of non-monetary criteria and defining of valuation functions for these criteria only (step 2.2)
- two-dimensional order regarding the values from 4.2; no unique order.
  In some instances, a rule like [max (effectiveness) and min (cost)] or constraints on effectiveness or cost may yield a best alternative (step 6.1)

3.1.2.2 Decision-Goal

Considering the import and comprehensive effects of projects for which analyses are conducted it has to be postulated that the overall objective of an investigation (decision-goal) should be a total and definite one.

A decision-goal and the system of criteria derived therefrom will be called total if it takes into account the whole of effects generated by the decision, otherwise it will be called partial. A decision-goal will be called definite if it can be derived consistently from the objective or system of objectives of the community. Decision-goals not fulfilling this condition are called subjective.

CBA claims to be able to help deciding which of the alternatives in a decision-situation leads to maximum social (economic) net-benefit.
Following the above distinction, this would imply a total decision-goal. If the goal is also to be objective, then it must have its foundation in welfare economics and the increasing or maximising of welfare must be the overall objective of the community.

Many recent investigations, however, have shown that it is impossible to derive a welfare-economic foundation for CBA (cf.[24] p. 35 et seq.).

The decision-goals of CBA, therefore, are not total onesbecause they have no foundation in welfare-economics (cf. [27] p. 14, 15). They are, moreover, not objectives ones.

Non-monetary effects are either not incorporated into a CBA at all or they are taken account of at the end of the analyses based on valuations of the decision-maker. If the decision is made solely by monetary benefits or costs, the non-monetary effects are valued by the decision-maker as being neglectable whether the decision-maker recognizes this or not. If the decision is made by taking these effects into account, it is founded subjectively from the beginning.

CEA and especially MAUA explicitly provide for the demands of the decision-maker, they are principally subjective. Their decision-goals cannot be classified as being total or partial a priori. Only after an overall objective has been supplied and has been operationalised in a hierarchy of (sub)objectives it is possible to say if the decisions to be made are efficient. The provision for subjectivity has both advantages and disadvantages.

The decision-maker has to prove that the decision-goals he has supplied are indeed objective ones. He either has to conduct their consistent derivation from the overall objective of the community or has to generate the necessary consensus. The decision-maker cannot be sure, a priori, that the decision-goal supplied is only a partial one. Therefore, he must, with all diligence possible, be comprehensive in defining this problem and objectives, and he has to prove that this has happened.

The methods are neutral as regards the decision-goal supplied. Therefore, they enable the decision-maker to supply, at first, a set of criteria which he thinks to be efficient and revise it in the course of investigation. The methods disclose the process od defining, weighting and applying the criteria.

Thereby, the decision-maker is forced to be clear about the consequences of his assumptions, and he is able to make specific alternations whose effects are also disclosed openly. Furthermore, third parties (e.g. for attaining a necessary consensus) are able to follow the assessment procedure and may even intervene. The decision-maker is not forced to monetarize effects for which market prices do not exist. He is free in his choice of units of reference, safe for the principle of the strongest possible manner of scaling; cf. chapter 3.123.3. Thus, he is able to incorporate all effects consistently into his assessment procedure.

3.1.2.3 Characterization of Alternatives

3.1.2.3.1 Interrelation of Alternatives

All methods assess alternatives which are able to fulfill the respective task independent of each other. The alternatives are complex, i.e. they encompass a multitude of (single) measures.

When, compared to the present situation, only one "new" alternative is to be assessed, a comparison of alternatives still is possible, if the present situation is compared with the new alternative where the present situation has been extrapolated under the maxime of "carrying on as before".

The implementation of the selected alternative requires financial means which have to be raised within the community budget, and this budget may lead to restraints on the implementation. Assuming that budget restraints are known at the beginning of the investigation (e.g. for construction and operation of a transportation system, at best a sum of x_1 and yearly payments of x_2 are available) they constitute a part of the decision environment (step 3.1 of process) which excludes alternatives either in preselection (step 3.2) or assessment (step 6.2). In CBA and CEA this is immediately recognizable. In MAUA, the transformation functions have to be defined accordingly.

3.1.2.3.2 Incorporation of Effects

The effects generated by a decision for an alternative may be classified under three aspects which combine freely.

a) positive
negative effects

This concerns the question if and to what extent an alternative improves or worsens a situation.

b) direct (so-called internal)
indirect (so-called external) effects

This distinction accounts for the fact that alternatives impinge on sectors which are not an immediate part of the object system and are not felt in it.

c) monetary
non-monetary effects

It is generally accepted to use monetary units as the empirical unit of reference (in the sense of the definition in chapter 3.112). Thus, monetary effects are those which are directly attributable to monetary transactions (e.g. fare revenues or personnel costs of a transportation system) or which can be determined by valuation rules which are objectively testable (e.g. market prices, linear depreciation of assets, capital values which have been computed by means of a (per consensus) accepted rate of discount.) Effects which require an act of valuation which is not objectively testable are classified as being non-monetary (e.g. valuation of savings in transit time or avoided number of accident deaths).

CBA whose primary decision objectives are monetary by method must also try to express indirect, and a priori non-monetary effects in monetary units. Effects for which this is not feasible can only be accounted for "per memoriam" (cf. [24] p. 38, 39). In so far, the assessment of alternatives becomes inconsistent.

CEA systematically differentiates between monetary and non-monetary effects. Their final assessment requires either a monetarisation of effectiveness or a utilisation of costs. Although such an evaluation of the "second" order is at first only based subjectively, it can, however, be made objective by consensus; cf. chapter 3.121.3.

MAUA transforms the monetary effects into non-monetary units of systems-utility. The assessment can be conducted in a methodically consistent way, and additional valuations, as in CEA, are not required.

With complex alternatives, usually the ability to recognize and incorporate all higher-order effects (e.g. fourth, fifth, and still higher order) is limited by the intellectual and information capacity of decision-makers and analysts. Because of this the incorporation of higher-order effects has to be terminated at some point. All of the methods have to contend with this limitation. An important, if not the most important part of the budget for an investigation is required for the acquisition of data. It is a fact of experience that usually many data are not available in the format necessary for the investigation, especially not the data for indirect effects. The activities for data transformation and generation usually are costly. Therefore, they tend to act as a brake to an incorporation of higher-order effects, given a fixed budget. The decision-maker must accept the fact that the budget of an investigation imposes limitations on the detailedness of an investigation, and thereby, its results.

3.1.2.3.3 Measurement of Effects

Translating Torgerson's definition (cf. [26] p. 14, 15) into the terms used here, the following can be said:

The measurement of an effect means an assignment of numbers to those quantities of the effect (attributes) to be measured which are encountered in the alternatives to be assessed.

To represent the effect, it is necessary that a one-to-one relationship between certain properties of the number system and the relations between the respective quantities of the effect to be measured obtain. The relevant properties of the number system are:

1) The numbers are ordered in sequence
2) The differences between numbers are ordered in sequence
3) The number series has a unique origin (zero).

There are certain types of scales:

a) nominal scales

None of the above properties obtain. It is only required to assign the same number (e.g. 0 or 1) to same quantities (property of identity).

b) ordinal scales

Property 1 obtains. Larger/smaller quantities are assigned larger/smaller numbers. Further statements cannot be derived.

c) interval scales

Properties 1 and 2 obtain. The differences between quantities may be validly interpreted, safe for a linear transformation, because of the missing unique origin.

d) ratio scales

All of the three properties obtain. Because of the unique origin, absolute statements about quantities are now permitted.

The statements possible in the respective types of a scale may be presented comprehensively, following Zangemeister ([25] p. 155):

Type of Scale	NOMINAL	ORDINAL	INTERVAL	RATIO
possible statements	equality diversity	← larger,smaller	← equality and diversity of intervals	← equality and diversity of sums, multiples and quotients
permissable transformation of measurement values	$x' = c$ c:= any discriminating attribute	$x' = f(x)$ f (x): monotone increasing function	$x' = ax + b$ $a > o$ (linear transformation)	$x' = ax$ $a > o$ (multiplicative transformation)

CBA uses ratio scales of the empirical unit of reference "monetary units" for those effects it measures. The measurement quantities are market prices, by principle. Where these are not given, substitute quantities (e.g. opportunity costs, willingness to pay) are used (of. [27] p. 5 and 131 et seq; [28] p. 67). As a foundation in welfare economics is impossible CBA is not efficient in the validity of its results - already in its monetarised part - because some quantities used, although being monetary units "in nomine", result from valuations of the decision-maker or even the analysts.

Furthermore, as the non-monetary effects are only described verbally, i.e. are not measured on any type of scale, they cannot be added to the benefit of an alternative without intervening acts of valuation. If no upgrading of verbally described effects by weighting, transformation and amalgamation is made at all, the effects monetarily measured are essentially useless because the postulate of the strongest possible manner of scaling has as its converse that the assessment can only be made on the lowest level of scales used in evaluation (i.e. in this instance on the verbal level).

MAUA uses interval scales of units of systems-utility. Effects not directly attributable to these are transformed to this scale level by valuation functions and weighting. Effects monetarily attributable, like costs and revenues, will be downgraded by utilisation. Effects which are nominally measurable usually will be treated in such a way as to convert them into conditions for exclusion of alternatives at preselection or assessment of alternatives (e.g. overall capacity and safety of a transportation system). Ordinally measurable effects will be upgraded by means of valuation functions whose limits and course are determined by convention.

An essential condition for the validity of this procedure is that the decision-maker must be able to express the importance he wants to assign to the respective partial objectives independent of the extent to which any single alternative may be able to contribute to this partial objective. Otherwise, a preselection would have been made implicitely. Furthermore, an effect must be defined in such a way that it can be fully described by a criterion or combination of criteria which is, in this very from not used to describe another effect, too.

To meet the above conditions the continuum of quantities for systems-effects has to be restricted to a domain of values $a_1 \ldots . a_2$. The bounding values of a_1 and a_2 can be thought of as "minimal" and "maximal" requirements. This means that below a_1 the (non-acceptable) quantities of the effect are not graded any further and that above a_2 a super-supply of the effect is not honoured by the decision-maker. Within the bounds $a_1 \ldots a_2$ the respective effect may then be evaluated indepedently.

The weighting factors of the criteria describe their relationship of substitution. The weights are non-empirical in the sense of the above definition. There is, however, a possibility of anchoring them empirically (cf. [26] p. 24, 25). This may be effected by interviewing persons affected by the decision outcome (e.g. users and operator of a transportation system). For this a lot of procedures exist (with or without information feedback) whose efficiency has to be tested in each instance.

CEA leaves monetarily attributable effects on the level of ratio scales. It upgrades effects which can be ordinally scaled to the level of interval scales to determine effectiveness. Methodical peculiarties do not result; respective requirements and possibilities have been presented in CBA and MAUA above.

3.1.2.3.4 Incorporation of Time

A substantial problem in assessing complex alternatives is the incorporation of time. Not all of the alternatives have thesame life-time, and the same effects may appear at different points of time and be of different duration in different alternatives.

The problem can be also found in the investment theory of business economics. There, it is treated by the concept of discounting, and it seems to be apt to generate temporal comparability of alternatives by discounting here, too.Suitable procedures would be the determination of capital values and annuities (cf.[28] p. 18 - 22). If one of those procedures is chosen the following assumptions and restrictions should be noted:

As of the time of decision no alternative is yet implemented, i.e. in terms of investment theory the view of new investment (problem of choice of alternative to be implemented) has to be taken. Therefore, statements about alternatives are comparable only if the same duration of investment has been assumed (problem of assumptions of reinvestment of amortised capital).

If capital values or annuities for alternatives are determined which are discounted with respect to the time of decision then it is assumed implicitly that the "law of prefering present to future needs" is accepted as valid (cf.[24] p. 146) for decision-making. This assumption may not always be acceptable, especially for the assessment of alternatives which generate indirect effects.

It is generally thought to be helpful in such cases to conduct sensitivity analyses with several "plausible" discount rates (cf. [24] p. 147; [27] p. 152).

Discounting can, by definition, only be applied to monetarily measured effects. In the interest of temporal comparability it has to be applied to these. For effects which are scalable only on a lower level, it is only possible to mention their time of occurrence and their duration. Then, the decision-maker has to construct his own preferences, i.e. valuation functions and weightings for his time system, if this has not been done already in the determination of his preference structure.

In CBA costs and benefits must be discounted (sensitivity analyses included). For the effects described verbally their time of occurrence and duration have to be listed. Temporal comparability of results does not exist because effects which should have been measured in utilities were monetarised and the discount rates adequate for this are not objectively determinable. The effects described verbally are not discountable and cannot be made comparable within the context of the method.

In CEA the monetary effects must be discounted. For non-monetary effects their time of occurrence and duration have to be listed. The method provides a possibility to relate them to the point of time of decision by generating a preference structure of time. If applied consistently, the costs K_i and the effectiveness W_i ($i = 1, \ldots, n$; number of alternatives) are comparable internally. However, as the costs K_i are ratio-scaled, the effectivenesses interval-scaled, no relation of cost K_i to effectiveness W_i of a single alternative is permitted and may also not be used in assessment. For this, additional considerations (determination of cost- or effectiveness limits) or valuations (utilising of cost or monetarising of effectiveness) are necessary; cf. chapter 3.123.3 and also[24] pp. 125 - 135. They can, however, be conducted in a methodically consistent way.

MAUA may be problematical as regards the monetary effects. Also for monetary effects a preference structure related to time must be generated because of methodical reasons. This requirement can be fulfilled within the method.

If, however, in the context of a MAUA monetary effects are discounted nonetheless, this is to be viewed as a simplification in generating the required time structure and not as a requirement immanent in the method. To what extent the quality of results will be affected by this simplification is a matter of instance. If the time structure has been consistently defined and applied, the systems-utility N_i of alternatives are temporally comparable and may be assessed up to a linear transformation of the unit of systems-utility.

3.13 Summary

The difficulties in assessing complex alternatives are in the decision objectives and the adequate description of decision effects.

In view of the danger that the system of criteria defined will usually be partial and may be a subjective one, those methods are to be preferred which openly disclose the process of determining objectives and preference structure and are able to treat it accordingly. Under this aspect, CEA and MAUA would seem to be preferable.

Regarding the measurements of effects, the requirements of scaling theory show that there is some natural level of scaling for every effect (cf.[26] passim and definition of Torgerson in chapter 3.123.3). The change from one level of scaling to another one is always requiring expenses in theory and/or valuation. As faults cannot be ruled out in this because of the complexity of the alternatives to be assessed those methods are to be preferred which require the least expenses in this respect. This especially, is CEA, then MAUA and at last CBA.

The investigation methods are only to be used in appropriate cases and projects of considerable importance in the urban transportation field. They represent standardized estimate works containing the subjective opinions of the decision makers and consultants. The subjective influence is mainly present in measuring and evaluating the total economical and so-called sozial costs and benefits. The degree of the objectivity obtainable in the test results is partially depending on the selected methods. In spite of all objections these procedures as a mean of precise decision preparation are preferable.

3.2 Importance of the Various Assessment Criteria

3.2.1 Need to Determine their Importance

For a comparison of two or more transport systems or for the assessment of improvements of individual systems it is necessary to consider the costs and benefits involved. Important factors in determining benefits are the weights/importances attributable to requirements and/or judgment criteria (cf. chapter 3.1).

Different groups of persons (users, transport and town planners, the general public and operators) will view the various assessment criteria differently. Not even within a group of persons will the importance attributed to a criterion be the same for every one; that means, a passenger under time pressure will evaluate waiting time differently from the passenger who is in no hurry. The importance attached to a criterion by a person is also dependent on a number of external, non-operational factors, such as the structure of the transport area, the quality of the existing transport systems, the number of passenger cars per inhabitant or per km of road in a transport area. Furthermore, the importance attributed to individual criteria such as seating quality and seat availability will be different in a highly industrialized country with a high rate of car-ownership compared with a "poor" developing country. Differences exist even between two cities of the same country.

Other influencing factors are the kind of transport used and the purpose of travel. For instance, a regular commuter will be more interested in speed of travel than the casual passenger (using the system for shopping or leisure). Another criterion is the "necessary degree of passenger involvement in handling and dispatching" or the information about using the system; the commuter will attribute less importance to this aspect, owing to the daily routine of using the system and/or the facilities provided by season tickets, than the occasional traveler who is not familiar with the system.

In order to obtain a clear view of the importance of individual criteria, it is necessary to interview a representative cross-section of the general public directly or indirectly concerned by a transport system. The more a group is representative, the more accurate will be the mean values and medians obtained for the relative importance of the criteria.

The requirement of representativeness of these surveys is very difficult to meet, for a number of reasons. For instance, the composition of the traveling public in terms of classes of the population, age groups and sex is not known. Moreover, at least for a certain part of the respondents the questions would be too complex.

In the past, transport operators have tried to improve the attractiveness of their services by means of technical and operational measures, wherever they felt that a minimum of input would yield a maximum improvement - of course generally from the view point of the operator. Objective criteria for a greater attractiveness of the services provided can only be obtained by listing the requirements of all parties concerned, by weighting these requirements within each interested sector (users, operators etc.) and by weighting the interested sectors in relation to each other.

3.2.2. Possibilities and Data for the Determination of Weights

In order to determine the importance of assessment criteria it would actually be necessary to carry out surveys among the interested persons of each sector; alternatively it would be necessary to conduct a survey among experts on the criteria of all interested sectors.

Up to this time there have been few surveys specifically geared to the assessment of systems (e.g. quotation of the Battelle Study [43] and the SNV Study [14]) and surveys conducted for more general purposes which produced basic indications of relative importance; for instance there have been opinion polls organised by a transport association and designed to produce information about the image of public transport enterprises [30].

However, these general purpose surveys among

- passengers
- drivers of passenger cars
- general public (opinion polls, household surveys)
- the management of transport undertakings

also produce results from which certain conclusions might be drawn, had a more specific survey been carried out.

For the purposes of the general surveys a limited number of motives/characteristics is offered for choice, of which only one or the three most important ones shall be named. The motives determining the modal choice can be formulated in a positive/ neutral (motive: time advantage) or a negative/prejudiced (motive: car riding is more dangerous) way. The method of interviewing is also relevant in this context, in that the description of the characteristics submitted to the interviewed person may influence the result. Further possibilities of influencing the results are provided by the presentation of the motives/characteristics (the use of key-words, use of interrogative or affirmative sentences) or by the way of listing or interpreting the meaning of a characteristic. Individual aspects of criteria, such as time or comfort can either be included in various criteria or only in one. The results obtained by such surveys are:

- the number of characteristics named
- an order of values; if the persons interviewed had to apply a given scale of values (1 = the characteristic concerned applies to a very high degree; 5 = it applies only insufficiently).

The importances of assessment criteria can be determined by a survey using a scale of values which provides for the desired graduation between the criteria. The frequency of naming a given criterion determines its place in the order of importance. If a criterion achieves a frequency of 70 % of all namings (if the totality of all namings is fixed at 100 %) this does not imply a weight of 70 %. So far, surveys among passengers, transport and town planners, operators, and the general public, intended specifically for the purpose of system comparison with the above mentioned assessment criteria.

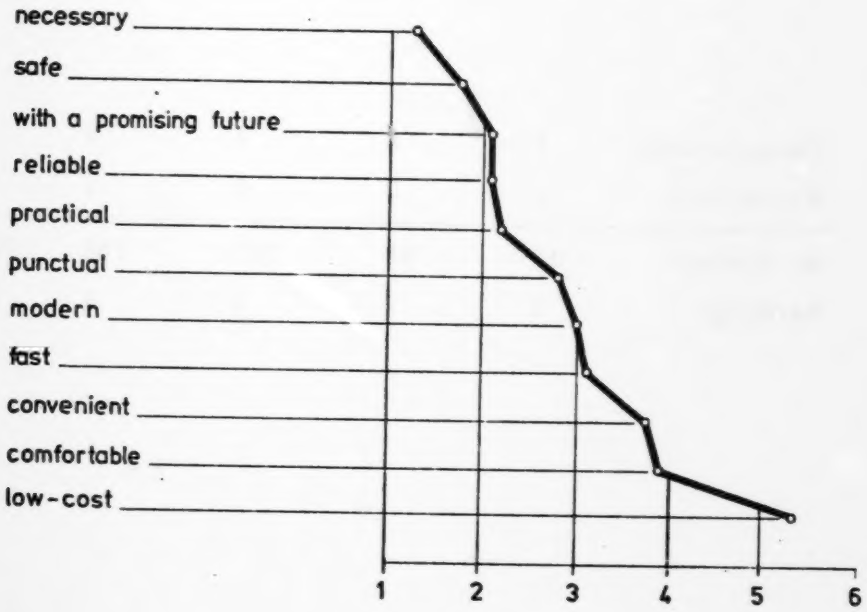
A two-step survey among experts, who should preferably belong to the sectors of transport planning, operation and policy, is capable of producing good results providing there is a feed-back of information. After determining an order of the assessment criteria in a first step of evaluation, it may have to be modified in a second step following a conversation and in the light of a possible comparison between the first order of values and the collective order.

3.2.3 Examples of Orders of Importances

In the following paragraphs one example is given for each survey conducted among

- passengers
- operators
- general public
- experts interviewed separately one the different sectors: users, operators, and general public.

In the course of an image survey, passengers of public transport were required to evaluate 11 characteristics of public transport. The results (according to [30]) were as follows:



value 1 = characteristic applies to a very high degree

If this result is compared with a survey among operators, required to establish an order of 5 characteristics [31] it appears that the results of the two surveys coincide to a very large degree.

Town	Frequency	Speed	Reliability	Cost	Comfort
Addis Ababa	1	4	2	5	3
Aleppo	2	3	4	1	5
Barcelona	1	2	5	4	3
.					
.					
.					
.					
.					
.					
Valenciennes	2	3	1	4	5
Winterthur	4	2	3	1	5
39 Towns:	86	98	111	139	153
Ranking:	1	2	3	4	5

An opinion poll conducted among the general public produced a similar order of priorities (with the exeption of the costs): frequency, speed, comfort (according to [12]). Fares are still a problem with passengers and the general public, a fact which operators still do not (wish to) recognise.

public transport should	all gainfully employed persons	all gainfully employed persons using public transport
be cheaper	1 (37%)	1 (57%)
run more frequently	2 (25%)	2 (34%)
provide shorter walking distances to the nearest stop	3 (21%)	3 (26%)
be faster	4 (10%)	4 (19%)
require fewer transfers	5 (9%)	5 (10%)
provide more comfort	6 (5%)	6 (9%)
total number of characteristics named 1)	(107%)	(155%)

1) The interviewed persons were invited to mention one or two characteristics so that the total number of characteristics named

could reach as much as 200 %. Gainfully employed persons responding to the interview mentioned on the average 1.8 characteristics.

A survey among experts on 27 criteria produced the following result [14]; for this purpose, the 7 most important characteristics were chosen from the sector users, accounting for 75 % of all weights.

characteristics for users	weights in % independent[1]		weights in %[1] dependent on distance of travel		
	min.	max.	min.		max.
speed			13,0	→	23,4
frequency of service	11,5	15,2			
direct routing/ transfers			8,6	←	11,4
punctuality	7,9	11,1			
seat availability			6,8	→	13,2
access			8,0	←	10,1
protection against atmospheric conditions of stops			6,2	←	8,0

1) The survey was conducted among commuters and casual passengers and for 6 applications with varying distances of travel;

→ illustrates the change of trend with increasing distance.

characteristics for operators	weights in % (all independent from distance of travel) min.	max.
reliability	31,9	43,5
capability of co-ordination with other transport systems	9,0	25,7
personnel requirements	15,4	18,9
operational flexibility	14,2	18,2
flexibility of the physical structures	6,9	13,4

characteristics for the general public	weights in % (all independent from distance of travel) min.	max.
physical integration into the urban form	32,2	37,0
environmental effects	29,7	30,8
development effect	22,5	30,3
primary energy requirments	7,5	10,5

The different sectors concerned have not been weighted in relation to each other, in the absence of which an overall effectiveness of a system cannot be established. On the other hand, this method makes it possible to update the importances of individual sectors depending on, and in keeping with, the preferences and the scope of general policy.

3.3 Degree of Fulfillment of Individual Assessment Criteria

As it is not possible to evaluate every system in respect of each assessment criterion first of all - independent of the particular system - certain characteristics such as

- track-guided - non track-guided
- with driving personnel - without driving personnel
- elevated guideway - underground guideway

are considered together, if, because of these, contributions towards a criterion are equal or similar. In addition to this e.g. a deviation in the degree of fulfillment of a criterion through a special systems characteristic has to be explained. Such a special system characteristic could be the headway technique of a small cabin system. The degree of fulfillment of the assessment criterions: capacity and reliability are influenced mainly by a special headway technique.

In some cases it may be necessary to consider in the context of such a systems group systems with special characteristics, such as magnet levitation techniques, if they are likely to affect the degree to which the group is able to meet a given assessment criterion.

3.3.1. User/Passenger Sector

Costs: Low costs are usually a concomitant of non-track-guided operation, with low traveling comfort. Improvements with a view to meeting passenger requirements will generally entail higher costs. Labour costs are a dominant factor of the operating costs. On the other hand, a reduction in labour costs is related to higher costs for fixed installations and vehicles and might cause higher overall costs. Furthermore, savings in driving personnel (for systems with automated operation) result in a personnel increase in the surveillance, repair and maintenance sectors.

Balancing the costs through fares is at the present stage for an operator hardly possible. The public hand has to compensate for the costs arising to an operator through political decisions such as servicing certain routes or for not being allowed to charge pupils.

Travel time/speed: Travel times on public transport may, on occasions, amount to a multiple of the time needed to cover the same distance in a passenger car. Transport systems which do not operate on a separate right-of-way but have to share the traffic space with other traffic incur longer travel times than passenger cars because of the stopping times necessary for picking up and discharging passengers. Walking distances to and from stops and stations are often longer than the distances to and from a parking place even considering the time needed to find a parking place. The time advantages inherent in dial-a-ride bus systems (absence of access times) are frequently lost due to routing detours. Despite the lack of a separate right-of-way, the taxi is the fastest mode of public transport, except during peak-hour traffic or on traffic routes where a rapid transit rail system with long distances between stops is available and therefore can compete favourably with the taxi in terms of travel time. Systems operating according to a non-stop direct-routing concept and on a separate right-of-way have time advantages over the private car, although newer automated systems provide for fixed stop operation.

With conventional systems, waiting times constitute sometimes a considerable handicap for travel time. Shorter waiting times may be expected in connection with demand-operated systems.

Walking Distances: One aspect of "inconvenience" involved in using public transport is attributed to access, i.e. the walking distances involved; the objective is to reduce them as far as possible. Preference is given to systems with short distances between stations. Where the distances between stations are long, (especially with high-speed rail systems), walking distances can be reduced by introducing feeder services. Taxis and dial-a-bus systems can involve very short walking distances.

Frequency of Service: Adaptation to changes in traffic demand can be achieved by changing the frequency of services and by the coupling together of vehicles in the formation of trains. Consequently, it is necessary to consider both technical and application-related aspects. Whereas with bus systems, adaptation to changing demand is only possible by changing the frequency of services, track-guided transport systems (conventional as well as newer large cabin systems) can also be adapted by train formation. Systems which operate a non-stop direct-routing concept do not normally provide for train formation (exception: "contact-free" coupled vehicles such as the ARAMIS system).

As far as frequency of service is concerned, there is a difference between new small and large cabin systems on the one hand, and conventional large capacity systems on the other in respect of performance during peak-hour traffic versus off-peak performance. Especially horizontal elevator systems (SLT-systems = shuttle loop transit systems) and small cabin systems (PRT = personal rapid transit) offer a nearly permanent operational readiness and thus a high frequency of service at all times. This means on the other hand, that they may involve longer waiting times during peak-hour traffic owing to the uneven distribution of the cabins in the network. The reverse is true of most conventional transport systems, i.e. high frequency of service during peak-hour traffic, lower frequency during off-peak hours.

Reliability (Punctuality and Regularity of Service)

Where public transport systems have to share their traffic space with private transport, their punctuality and availability is severely affected. But also track-guided systems with automated, unmanned operation can suffer a considerable amount of irregularity and delay during periods of high traffic demand (especially if a small cabin system has to accommodate a large number of passengers), or due to passenger interference (e.g. by delaying vehicle departure). In terms of punctuality and regularity of service, man-driven, track-guided systems operating on a separate right-of-way show the best performance.

Change of Destination During the Journey: Change of destination during the journey is possible by

a) alighting at a stop other than the originally intended destination;
b) transfer at an appropriate station and continuation of journey on another means of transport;
c) oral modification of the transport order;
d) completion of the journey and booking of a connecting trip.

The variants a) and b) (for conventional fixed-route transport services) and d) (for non-stop direct-routing) systems are of equivalent value. The best flexibility c) is provided by the taxi. This degree of flexibility can only be achieved by the dial-a-bus system, if the driver communicates the change of destination to the dispatch center and the dispatcher can comply with the new request on the planned route.

Individuality, Privacy: The degree of privacy offered by the private car can only be obtained by non-stop directly routed small cabin systems - as the small cabin is used either by one person or in a small group, in the desired company of people. With larger cabins, the likelihood of riding alone or in private company is rather reduced (if at all possible, only during off-peak hours). With large-capacity vehicles, complete privacy of travel is not attainable, however, certain measures in the fields of compartment design and seat arrangement can enhance the impression of privacy.

Direct Routing/Transfers: This criterion is best met by directly routed small cabin systems, taxis and dial-a-bus systems. Depending on the structure and density of their route-network, transfers are possible or even necessary with most conventional fixed route systems. Also newer transport systems, like automated large cabin rail systems provide for fixed route operation and transfer facilities. Networks based on a shuttle loop service (horizontal elevators) require a great number of transfer facilities, as neither a shuttle nor a loop can provide an indefinite length of line or number of stations (restrictions imposed by the frequency of service, reliability etc.).

Protection Against Atmospheric Conditions: The stops of bus and tramway systems afford the lowest degree of protection against atmospheric conditions. Underground stations score better than open and elevated stops (suspended railways). Regardless of the system, all stops can be equipped with partitions between platforms and right-of-way and thus provide better protection against bad weather. The best protection is offered by air-conditioned underground stations, as planned for the Metro system in Washington.

Information About Using the System: In recent years conventional systems have required a higher degree of passenger involvement (= low contribution towards meeting the criterion) on account of considerable reductions in their labour force.

With notable exceptions it is rare that information is available at the stop about line routing or the exact location of stops. Time tables and tables and fares are displayed at stops in only a few countries. Advice and guidance form the operating personnel is generally very limited and given in a rather succinct manner.

Systems which operate on a separate right-of-way usually possess larger and better equipped stations and provide better and more detailed information. It may be assumed that the degree of passenger involvement with novel, automated (unmanned) systems is not much higher than with conventional systems, yet of a different nature. The lowest degree of passenger involvement is needed for riding a taxi or a dial-a-ride bus (with a normal dispatch system); all the passenger has to do is to indicate origin and destination of his journey, on which basis the operator or dispatcher/driver will determine route, fare and departure time.

There is no need for information concerning access routes, time tables, fare structure, handling of ticket machines and turnstiles, routes and transfer.

Boarding and Alighting Conditions: When determining the degree of target achievement, several of the factors covered in chapter 1.2.11 have to be considered. As far as boarding and alighting conditions are concerned, the need to climb up a step (e.g. bus) may be as much of a disadvantage as the need to bend over to get into a passenger car (taxi). Of lesser importance are door width, design of door space, door opening and closing mechanisms. Tramways and buses, taxis and small cabin systems are very far from meeting the target values, as they require passengers to stoop for boarding the vehicle. Rapid transit rail systems with a minimum difference in level between platform and the upper edge of the vehicle floor, door heights of ≥1.90 m and door widths of ≥1.25 m as well as catch areas in the passenger compartment go a long way towards meeting the target values.

Driving Noise: Sound-absorbing measures are being taken for all conventional transport systems. These efforts include equipment of railways with rubber-suspended and rubber-coated wheel disks, noise-absorbant permanent way constructions, and in other sectors: noise insulation of the passenger compartment, encapsulation of the engine or motor, noise attenuation of the compressors and the dynamos. As regards the design of new cabin systems, there are indications that manufacturers attach great importance to reducing noise levels. Some cabin systems already in operation run at low noise levels (e.g. systems with rubber wheel chassis and electric, rotary or induction motors). Levitation systems would expected to produce low noise levels.

Smoothness of Vehicle Operation: As the degree of target achievement is determined by various elements of the vehicle and the guideway, these have to be taken into account. Because of their smooth rail surface, railways could provide perfect smoothness of running in direction of travel; however, this performance is affected by sinoidal and lateral movements of the wheel sets. With rubber-tyred road vehicles, the condition of the road surface, irregularities, slopes or gradients have an impact on the smoothness of operation. The performance of rubber-tyred systems operating on separate rights-of-way is not entirely satisfactory in terms of smoothness of running. Presumably the best running qualities can be achieved with non-contacting support and guidance techniques. However, day-to-day practical experience with their operation is not yet available.

Air Conditioning (Heating and Ventilation): Non-stop direct routing systems with an air conditoning equipment that is adjustable to individual needs come closest to meeting the target values, as they are not affected by changes in temperature and climate, due to stopping for boarding and alighting of passengers. Similar classification must be given to systems where trains and stations are fully air conditioned. However, for economic reasons, fully air conditioned stations will remain the exception rather than the rule. Especially when considering, that it is only practicable where the station is closed as much as possible (to the track and towards the entries and exits). Non-airconditioned vehicles and open stops such as tramways and buses, must be rated low.

Acceleration, Deceleration and Jerk: As some public transport systems share the road with private transport, they have to adapt their accelerations and decelerations to the flow of private traffic. It is not only the extent but also the frequency of these movements which account for the low rating of these systems. Especially buses without automatic transmission must be rated lower than those equipped with automatic transmission. With acceleration, deceleration and jerk values equal, systems carrying only seated passengers are preferable to those also carrying standing passengers as the effects of acceleration, deceleration and jerk are more uncomfortable for standing passengers. As a rule, systems which operate on a separate right-of-way show a better performance than those running on public roads. Non-stop direct-routing systems come closest towards meeting the target values as accelerations, decelerations and jerk caused by intermediate stops do not occur.

Harassment, Vandalism, Criminal Acts: Here again a number of factors have to be considered together. During darkness and off-peak hours waiting at a stop is equally unpleasant (and dangerous) with all systems. Differences are due to the length of waiting time and the degree of station surveillance provided either by personnel or by television monitors. Inside vehicles, protection can be provided by the driving and crew personnel. Where the operation of the vehicles requires the presence of a driver, he can sometimes directly survey the passenger compartment (e.g. bus). This is preferable to all other systems of surveillance. Rapid transit railways offer a lower degree of passenger protection as the driver cannot see what is going on in the other cars. Different vehicle configurations, such as a single compartment, articulated vehicles or married pairs with through passage from one car to the other can increase the degree of target achievement, by providing better passenger protection, both self protection and mutual. With increasing automation and constantly decreasing personnel the amount of harassment, vandalism and criminal acts tends to go up.

Transportation of Luggage: Large cabin and large capacity vehicles normally do not present any difficulties with regard to luggage transportation - apart from the difficulties connected with boarding and alighting, access, and elevated or underground stations. With small cabins, the carriage of bulky luggage such as wheel chairs, prams or bicycles may be difficult. Regarding their contributions towards meeting the target values there are, however, differences between the various systems: unlike the taxi, some small cabin systems like the Cabinentaxi of MBB/DEMAG can take the above mentioned types of bulk luggage.

As regards stops or stations of different transport systems, differences exist only in respect of access or exit for passengers with bulk luggage. Theoretically, all systems could provide baggage lockers although they are hardly suitable for open stops.

Consideration of Special Classes of Passengers: Of the many aspects mentioned under chapter 1. 2. 18 dealing with the requirements of special classes of passengers, only few, such as steps for boarding and alighting are system-specific. The most important of these system related requirements are largely identical with those referred to under

1. 2. 3	Walking distances
1. 2. 10	Information about using the System
1. 2. 11	Boarding and alighting conditions
1. 2. 13	Smoothness of Vehicle operation
1. 2. 15	Acceleration, deceleration and jerks.

Because of the existence of different classes of special passengers, reference is made to the information included under these chapters.

3.3.2. Town and Traffic Planning Sector

The Form of the Services Provided: Systems can only be evaluated in connection with an actual application as only the typical characteristics of a given condition permit to determine how far a system meets the desired objectives.

Accessibility/Area Coverage: The highest level of accessibility and area coverage is obtained with systems capable of using public roads. In this context, the taxi capable of reaching every passenger at every place must be given the highest rating. Dial-a-bus systems with door-to-door traffic are more or less equal in terms of meeting this target. A long way further down the scale follow all fixed-route systems, among which the track-guided systems have to be given the lowest rating because of their low degree of flexibility and the high investment cost involved.

Capacity: Evaluation of this criterion must be based on a given application.

Physical Integration into the Urban Pattern: The greatest contribution towards meeting this criterion is made by systems capable of using the traffic space of public roads (such as buses and taxis). Overhead contact wires for trolley buses and tramways lower the degree of target achievement.

Systems with a separate right-of-way generally do not integrate well into the urban pattern because the protection of the guideway from other traffic requires the construction of fly-overs, ramps, over- and underpasses which affect the general aspect. The amount of elevated, grade-level and underground sections of any route network depends on each specific application. Therefore, it is not possible to estimate the degree of target achievement for systems with a separate right-of-way. For instance, railways employing vehicles suspended from an overhead track can have the same amount of underground sections as guideway mounted railways.

Influence on Public Transport Patronage: Systems operating at high speeds, such as rapid transit railways, or buses running on separate bus lanes or express ways, improve the modal split in favour of public transport patronage, as demonstrated by the Lindenwold Line+) and Shirley Highway++) in the USA. Influence on the modal split, with a view to increasing the competitiveness of public transport versus private transport in terms of speed of travel is most easily provided by public transport with an adequate proportion of separate right-of-way.

+) Rapid transit railway system between the city of Philadelphia and the suburb Lindenwold.

++) Bus lane on a highway in Washington D.C.

The effect on the modal split achievable through fares can only be compared if the overall economic costs are used as basis of comparison for all systems, including the private car.

Automated systems operated without driving personnel must be rated higher than conventional systems if their frequency of service is considerably higher.

Design of Transfer Facilities: Systems capable of automated operation require greater investment outlay at junctions and intersecting points than conventional systems. Road systems for instance do not normally require major overpasses or multi-storey buildings for their transfer points. High-capacity systems require larger stations than low-capacity systems which in turn reflects on their transfer facilities. Nevertheless, even for low capacity fixed guideway systems, the amount of physical construction may be considerable, as for instance, for off-line stations, or where a small vehicle width commands longer platforms and pre-sorting of passengers.

Disruption of Traffic During the Construction Period: The smallest amount of construction work and therefore a minimum of disruption of traffic during the construction period is caused by road systems, such as buses and taxis; the renewal of a road pavement, the construction of an off-line bus stop or the setting up of shelters is normally a matter of hours or days, where - as the new construction, re-construction or extension of a tramway line causes much greater interference with traffic. It is assumed that the construction of elevated systems causes similar disruption as the construction of a tramway line although this may vary depending on the method and process of construction (use of pre-fabricated parts; method of riveting, welding, steel casting of concrete etc.). Even greater differences (in terms of traffic interference) exist in the field of tunnel construction between the more favourable shield tunnelling method and the open-cut construction. Any assessment must be related to actual applications as the amount of underground and bridge structures is not system-specific, but is determined by local conditions and topography.

Effect on the Urban Form: The higher the capital investment involved, the greater becomes the need for coordination between traffic and town planning. The relatively low impact on the urban form caused by taxis and buses in smaller communities will not give rise to negative evaluation. By contrast, for big cities, track-guided systems are considered more likely to avoid uncontrolled urban sprawl as illustrated by the city of Los Angeles (on account of the effect of concentration on the traffic and building structures).

3.3.3. Community/Environment Sector

Safety: Owing to their capability of separating different modes of traffic, different passenger volumes, speeds and acceleration/deceleration capabilities, as well as their capability for partial or total automation (thus creating greater independence from human error), systems which operate on a separate right-of-way reach a high level of safety. To what degree a system is capable of achieving the desired level of safety is, however, also dependent on the safety measures and precautions taken not only to avoid human error, but also sabotage and destruction. But as these measures are not yet generalized, as would be appropriate, the safety rate of rapid transit systems can be as low as that of buses. Taxis cannot be considered as being safer than private cars.

Energy Consumption: The parameters which determine type and amount of energy consumption are described in chapter 1.4.2. As electrical energy can be produced without petroleum electrically driven systems have to be given the highest rating, even considering the high losses involved in electric power generation and distribution. Positive evaluation factors are: certainty of the power supply (large degree of interchangeability of the primary energy input), but also the capabilities for energy recovery and the high efficiency of electric motors. In order to achieve the same transportation output, combustion engines and electric motors require about the same input of primary energy. However, petrol consuming combustion engines lose more energy due to their low efficiency and during the conversion process at the refinery (petrol = 5%; diesel = 10% losses). The energy losses of electric motors result from the low efficiency of the power conversion process at the power station, from distribution losses, and from conversion losses in the motor.

Emission of Polluting Substances: As low-polluting combustion of energy in power stations is technically and economically feasible, electrically driven systems are preferable to other systems. However, linearelectric motors have a lower efficiency than electric rotary motors, which means that they cause more pollution, although not in the immediate area of operation. With vehicle mounted combustion engines, the emission of exhaust gases is mainly determined by the various operating conditions of the vehicle, by its level of maintenance, as well as other factors. The propane/butane gas engine is preferable to the diesel engine and the latter is preferable to the gasoline engine.

Pollution is directly proportional to the level of energy consumed, therefore, consideration must also be given to such factors as resistance to forward motion, load factors etc. when evaluating the level of emission per output in terms of passenger-kms. More detailed conclusions can only be made on the basis of actual applications.

Noise Levels: Only some of the criteria described under 1.4.5. are system-specific. The greatest contribution towards meeting the target values are made by systems driven by induction motors, with magnetic support and guidance and operation at low speeds. A predominant factor in evaluating noise levels must be the consideration of the level of the guideway (underground, grade-level, or elevated) which in turn depends on the application. Low ratings must be given to systems which operate on public roads (bus and taxi) without a separate right-of-way, as they are generally fitted with combustion engines, run at maximum speeds of about 50 kmh and are equipped with patterned rubber tyres (thus producing engine, driving and rolling noises).

Space and Surface Requirements: Multiple usage of the road space is an advantage with systems which can share the available road space with other road users and with private transport (tramway, bus, taxi).

In terms of surface requirements (traffic surface per passenger carried) track-guided systems score better than other systems, as their additional "unused" clearance allowing for the lateral vehicle movements due to play, material wear and cushioning are minor.

Systems operating on a separate guideway can only be evaluated in connection with a concrete application, i.e. if the amount of right-of-waythat is underground, at ground-level or elevated is known. Systems with off-line stations require more space and therefore have to be rated lower than systems with on-line stations.

Capital Requirements: This criterion can only be evaluated on the basis of a given application as capital requirements are largely determined by the construction levels of the guideway and stations. Elevated systems can be built for about 1/3 or 1/4 of the money needed for the construction of underground tracks.

Systems with a high route capacity (such as the Metro system in Paris) require wide vehicle cross-sections and therefore wide tunnel cross-sections. Track costs increase with the width of the tunnel cross-section. If construction costs are, however, related to route capacity, low capacity track-guided systems may cost three times the amount of high capacity systems.

The capital requirements for vehicles mainly depend on their technical equipment (equipment for automated operation, air conditioning etc.). Related to the number of passengers carried, buses are the least expensive means of transport. Related to the same factor track-guided vehicles, such as rapid transit vehicles (underground railways, suburban railways) cost two to three times as much as a bus, and new-type small and large cabins (Morgantown PRT) up to eight times the cost of a bus.

Suitability for Goods Transport: Today's short-distance transport systems carry only negligible quantities of goods. Therefore, conventional systems have to be considered as lesssuitable for goods transport. Among new transport systems, those providing for direct-routing and non-stop operation - and possibly equipped with special vehicles - are more suited for goods transportation, in particular if the size of their vehicles permits the carriage of certain commodities, such as bulky goods.

3.3.4. Public Transport Operators Sector

Reliability, Safety and Security, Low Failure Rate: As this criterion depends on a great number of factors, it is very difficult to indicate how well individual systems can meet this criterion. Therefore, only a few aspects will be mentioned.

The sharing of the right-of-way with private transport enhances a system's proneness to failure while at the same time improving the possibilities for a reduction of the effects of failure. Systems with a separate right-of-way have the lowest level of proneness to delay. Where vehicles run on rubber tyres and an unheated guideway, the system's reliability and safety are reduced during winter time by atmospheric conditions.

Passengers or other unauthorized persons can interfere with the safe operation of unmanned vehicles, thus reducing their standard of reliability and safety.

Vehicle Size: Operators are interested in vehicle size out of cost considerations and from the point of view of operational flexibility. In addition to the amount of capital needed for the purchase of vehicles, it is important for them to know a vehicle's period of depreciation and interest for costing which determine the annual costs of service of capital. In many cases, service of capital per passenger decreases with increasing vehicle size.

Generally, a higher service of capital per passenger is required for track-guided vehicles than for others. The following situation applies in the Federal Republic of Germany:

Name of system	price per vehicle +) in 1000 DM	life time years	passengers per vehicle	annual service of capital per pass. in 1000 DM
Cabinentaxi	20	10	3	0,99
H-Bahn	100	15	16	0,73
Tramway (6-axled vehicles)	600	20	115	0,53
Underground railway Munich	1.200	25	290	0,39
Taxi	25	5	4	1,57
Bus	120	8	71	0,29

+) per January 1975

Small vehicles require relatively more maintenance and servicing than large ones (cf. 1.5.2.). Hence, their contribution towards achieving the target values in terms of the overall costs of vehicles, related to size, is low.

Operational Flexibility: It covers two aspects: a system's capability to adapt to short and medium-term changes in traffic demand and its adaptability to abnormal situations. For operators the first aspect is of greater importance than the second. This criterion is best fulfilled by automated small and large cabin systems, as they can adapt even to extreme traffic demands at all times, during peak-hours and off-peak-hours. However, as concerns the adaptability to abnormal traffic peaks, large capacity systems, like rapid transit railways score better than cabin systems because of their greater standing room capacity. This comparison only applies to cabin systems that are equipped with an optimum number of seats.

Systems with off-line stations and very short headways and systems providing for the coupling together of two and more units have a favourable rate of target achievment.

Flexibility of the Infrastructure: This criterion is best met by non track-bound systems using the traffic space of public roads. Depending on the nature of track-bound routing, and the structure of the network, the costs for route relocations or extensions tend to increase. While for instance changes of the overhead contact wires of trolley buses are relatively easy, comparable changes on tramways (contact wires and rails) require much greater constructive investment. Extensions of loop-shaped networks are very difficult, therefore, their flexibility is low.

The flexibility of the network and the costs involved in physical changes largely depend on whether the right-of-way is at surface-level, underground or elevated. Therefore, the degree of target achievement of individual systems with a separate right-of-way can only be determined individually, depending on local conditions.

Personnel Requirements: The prime objective of any operator is to provide a high level of service with a minimum of personnel. Systems running on a separate right-of-way can save driving personnel if
- there is still scope for higher turn-round speeds
- the operation is automated.

Based on passenger-kms, the proportion of the driving personnel of the total labour force increases in the following order:

- cabin systems
- rapid transit systems
- tramways
- buses
- taxis.

Concerning the total personnel requirements of new transport systems, there is still a great deal of uncertainty. According to a study conducted in the USA, the Airtrans-system in Dallas/Texas [33] requires 2.6 employees per vehicle. This compares with the traffic personnel requirements of other systems (i.e. driving, surveillance and depot personnel) as follows:

- buses have an average requirement of 2.4 per vehicle (this is a mean and median value established for all public transport operators associated with the VÖV = Association of Public Transport Operators in the Federal Republic of Germany),
- tramways need 2.3 to 2.4 persons per vehicle (also VÖV undertakings),
- rapid transit railways vary between 1.4 (underground railway in Hamburg) and 3.0 per train unit (urban railway in Munich).

With conventional systems, the personnel requirement per vehicle, based on the total personnel requirement is > 3 per vehicle or train unit. This unfavourable relationship is improved when related to seat-km or still better to passenger-kms. On this basis, rapid transit systems have a personnel requirement of 1 per 1 million passenger-kms per year, buses need 3.5 to 4.5 persons per million passenger-kms per year while dial-a-ride and small cabin systems are expected to need as many as 16 to 17 employed persons per million passenger-km per year [14].

With large cabin systems, the personnel requirement mainly depends on the operating technology used. Therefore, the degree of target achievement can only be determined in careful consideration of the operating techniques.

Maintenance and servicing relate to vehicles and infrastructure alike, as any increase in personnel or in material requirements for purposes of maintenance and servicing are equally unfavourable.

Track-guided systems sharing the traffic space with private transport (tramways) and automatically driven (unmanned) cabin systems require the greatest amount of maintenance and servicing.

Tramway track maintenance involves a great deal of cost and effort for the operator while the maintenance of the roads used by buses is not a responsibility of the bus operators. Where a system operates on a separate right-of-way, its vehicles cannot be damaged by other traffic. On the other hand, automated systems operating without driving personnel have other drawbacks affecting the degree to which they can achieve the target value. Automatic operation requires very complex and delicate equipment, which cannot be fully protected against vandalism. This demands a high amount of maintenance and servicing.

With conventional rail systems operating on a separate right-of-way, the necessary amount of maintenance and servicing is 34 % of the overall operating costs, with buses it is 24 % [33].

The proportion of maintenance and servicing personnel of automated (unmanned) systems is (according to [23]) 50 % higher than of conventional rail systems. It may therefore be assumed that the proportion of maintenance and servicing costs in the total costs is correspondingly higher.

Economic Efficiency (Operating Costs, Capital Costs): How much of the overall costs or the operating costs can be covered from fare and other revenue depends on the nature of the traffic system and the level of fares that is politically justifiable and that the users are willing to pay. It is possible that the users of non-stop direct-routing systems will be willing to pay a higher price for a more attractive service than for conventional fixed-route systems. But as such systems incur very high costs, the higher fares they may be able to demand do not necessarily indicate a higher economic efficiency.

The concept of economic efficiency can be misleading unless a system's advantages and benefits in the various sectors (passengers, neighboorhood) are duly taken into account (cf. chapter 3.1). In the Federal Republic of

Germany, many tramway systems have been discontinued partly because operators are primarily only interested in economic efficiency.

Systems with a separate right-of-way can be justified on the following additional grounds:

- if it is necessary and possible to relieve a road from some of its traffic;
- if other advantages are likely to arise for users, operators and the general public (e.g. higher transport speed, fewer failures, better noise insulation, urban land use effects etc.)

In their evaluation of economic efficiency, public transport operators do not always include interest payable on publicly funded investments. Therefore, economic efficiency from the point of view of operators is measured by the proportion of the operating costs that can be covered from fare revenue. This approach to economic efficiency is therefore concerned with personnel, maintenance and servicing, energy and other consumption, listed in their order of priority. The systems with the highest operating costs are to be placed at the lowest level of target achievement. Concerning the economic structure of transport systems, reference is made to those other criterias which are part of the assessment.

Suitability for Coordination with Other Transport Systems:

The capability to coordinate the capacities of two transport systems at their connecting points is largely determined by the specific application, therefore, it cannot be considered in the context of this evaluation.

In terms of suitability for coordination with other systems, direct routing concepts make the smallest contribution towards target achievement, as transfer from another system to a directly routed system involves an individual process of vehicle dispatching and destination coding.+) Other demand operated systems like horizontal elevators can be better coordinated with other systems. Passengers can immediatly board the arriving cabins, together with other waiting passengers; and as a rule desired destination can be selected on board.

If time-tables are coordinated and providing there are no other operational difficulties, transfer with the same ticket between two systems operating according to a schedule is fundamentally possible, in case without time loss. Where this is not possible the systems must be given a lower rating.

+) before departure or when buying the ticket for a given destination, in the Cabinen Taxi System the individual or season ticket has to be coded; the coded ticket is then inserted in a ticket reading machine on the platform which calls a cabin and tells it the destination.

Adaptability for Technical Progress: Basically and in a long-term perspective all systems with a separate right-of-way are adaptable for technical progress (with the ultimate objective of fully automated operation). This is also illustrated by the development of the bus from a manually operated mode of transport to a dual-mode system with fully automated operation on a part of its route network; in that case, however, the bus changes as a system (mutation).

The conventional bus operating on public roads has no scope for fully automated operation.

Systems with a separate right-of-way make the highest contribution towards target achievement because it is easier to change to fully automated operation. But this also depends on how well the system can be protected against external interference.

3.4. Assessment of Component Developments

The further new development of short-distance transport systems currently appears to be closely linked with the development of components which will imrpove specific system features or reduce costs. The following chapter deals with a number of systems characterized by intensive component development.

3.4.1. Drive/Motor, Transmission

For the purposes of vehicle propulsion, the power needed for locomotion can be produced either

- on the tractive unit of the vehicle, or
- outside the vehicle.

The following three types of engines or motors can be used either alone or in combination (hybrid propulsion systems):

- combustion engines
- electric rotary motors
- electric linear motors.

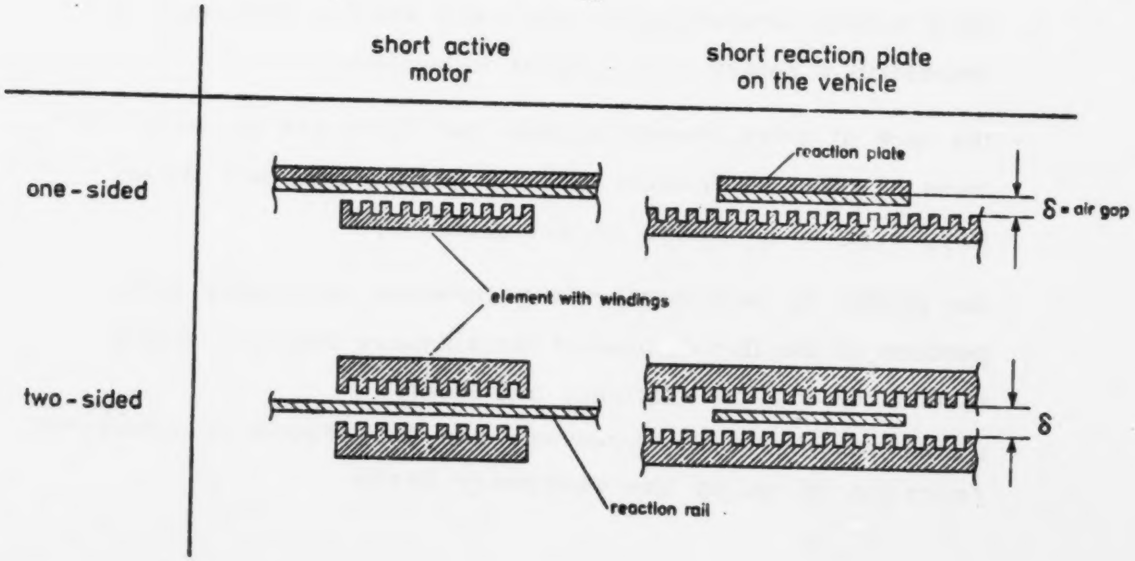
The most interesting development is that of the linear electric motors which until now have not yet been utilized for existing short-distance transport systems. Although the efficiency of the linear motor is lower than that of the conventional rotary motor - due to the necessity of a relatively wide air gap between the primary and secondary parts of the motor - they have some major advantages for transport systems:

- they can dispense with equipment for transmission and forward motion (transmission gears and wheels) necessary to transform a rotary into a linear movement;
- the lack of drive wheels implies that there are no problems of adhesive friction between friction gear and guideway, e.g. on gradients or wet guideway;
- the ability to calculate braking distances accurately (indipendent of the fluctuations of the adhesive friction), helps to enhance system efficiency and safety;
  disadvantageous is, however, the dependence on adhesive friction if using the emergency brake

- the motor is insensitive to dirt and shows a high reliability and life expectancy;
- due to the lack of revolving parts, there is no mechanical wear and tear;
- because one part of the driving system is mounted in the guideway, vehicles can be built lighter and therefore consume less energy.

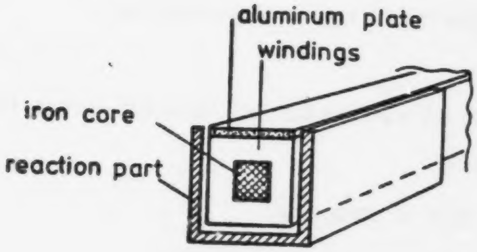
Linear motors are being tested for new transport systems in connection with contactless support techniques as well as with wheel support systems. Linear motors are more frequently travelling field motors, similar to three-phase rotary motors. They can be broken down into the following groups:

- synchronous or asynchronous motors - depending on the electric mode of operation (exciter principle),
- short primary and short secondary linear motors, depending on which part of the motor - primary or reaction part - is vehicle-mounted;
- single-sided or double-sided motors, depending on the arrangement of the stator = primary part (on one or both sides).


short active motor
short reaction plate on the vehicle
one - sided
two - sided
reaction plate
δ = air gap
element with windings
δ
reaction rail

Despite their quadruple air gap, double-sided linear motors are capable of transmitting the same amount of power as a single-sided motor, but they have guidance problems (the reaction rail is enveloped; at switch points, however, it has to be interrupted or moved like a switch blade). The disadvantage of the single-sided motor is caused by its single-sided magnetic pull which can be five to fifteen times as strong as the tractive force [34].

A special type of linear motor is the transverse flux motor, one version of which is characterized by a U-shaped reaction part enveloping the primary winding on three sides (see below):



Transverse flux linear-motor

Although this type of linear motor has relatively high efficiency - owing to the low magnetic losses - and a good thrust/weight ratio (o. 44 KW/Kg), it has problems in connection with switch passing (similar to the double-sided motor).

The disadvantage of asynchronous linear motors lies in their dependence on special devices for asynchronous starting (controllable frequency converters). Their advantages are to be seen in the nearly twice as high thrust forces compared with the synchronous linear motor [35].

Linear motors may eventually be found preferable to electric rotary motors, for instance in cases where the above mentioned advantages (e. g. in case of extreme gradients, where exact braking is necessary for automatic operation, or owing to their advantages in the fields of maintenance and repair) offset their higher energy consumption.

Electric rotary motors can be broken down into:

- d c motors,
- mixed a c/d c motors,
- a c series conduction motors,
- three-phase motors.

D c series motors are usually used for tramways and rapid transit railways.

In spite of long operational and developmental experience with d. c. motors further improvements and developments are still being sought, with the main emphasis being on the following aspects:

- reduction of motor weight and volume (e.g. by mounting two motors per bogie instead of one, with consideration to weight and volume of transmission equipment);
- increase of efficiency;
- reduction of noise (e.g. use of engine cooling fans);
- low maintenance and servicing requirements;
- insensitivity to climatic conditions.

Individual problems are brush sparking which can be reduced by sheet metal housings; or selection of proper insulation procedures and materials for windings which are capable of increasing the efficiency of these motors as well as their life span and safety against failure.

Mixed a c/d c current motors (universal motors) combine the advantages of a c traction (e.g. low supply losses and great distances between sub-stations) with the advantages of the d c motor. The motor is supplied with a basic proportion of d c current and a hereodyne a c current portion. As the development of semi-conductor technology advanced, adjustable transformers with rear position rectifiers were replaced by controlled rectifiers (gating control). As a c current networks are rarely designed to serve only short-distance transport, combined a c/d c motors will be used only where short-distance transport shares tracks with long-distance traffic.

The classical traction motor for a c current systems is the single-phase series motor (e.g. for 16 2/3 Hz or 50 Hz systems). It is mainly used for locomotives.

With the three-phase motor, which can be used as synchronous or asynchronous motor, the problem of speed control can be solved at a reasonable expense only by means of electronic control equipment. The advantages of the asynchronous motor over the commutator motor are, for instance, the following:

- direct transition for running and braking
- universal engine performance and high thrust utilization of the rotating field,
- reduced requirement for maintenance and servicing due to the absence of a slip ring and commutator.

Three vehicles of the Cleveland Transit System driven by a frequency converted asynchronous motor have been successfully tested over recent years.

Combustion engines are thermo-mechanical energy converters carrying their energy supply on board the vehicle. The most important of these types of engines are:

- Diesel engines (buses and rail vehicles),
- Otto engines (passenger cars, taxis).

Just as passenger cars and taxis can be equipped with Diesel engines, buses can be fitted with Otto engines. The advantages of the Otto engine, such as light weight and low noise are offset by considerable disadvantages: high energy consumption and unfavourable exhaust gas composition. Diesel engines, by comparison, can even remain under the limit values set in California in 1975 for permissible exhaust gas components. Even the limits envisaged for 1977 can already be complied with to a large extent. The further development of Diesel engines is characterized by efforts aiming at noise reduction (encapsulation of the engine), and reduction of exhaust gases (e.g. boosting, pre-combustion chambers, or catalysts).

Other combustion engines which for a number of reasons (e.g. higher energy consumption, mechanical problems, weight) have not yet been able to prevail over the Diesel and Otto engines (cf. 2.2.2.5) are:

- the gas turbine
- the Wankel engine
- the steam engine
- the Stirling engine
- the liquid gas (propane/butane) engine
- the natural gas engine.

Operation of combustion engines with new types of fuels is another trend of development in this sector, also aiming primarily at a reduction of exhaust gases. Special reference must be made in this context to tests with hydrogen and methanol (methanol can be used in dual-fuel gasoline/methanol operation, in conventional combustion engines as well as with new propulsion systems, allowing even for a stepwise replacement of methanol for gasoline).

Improvement of the low energy density of liquid hydrogen is the object of tests conducted with metal hybrid tanks. However, at the present stage, it is not yet possible to assess the future prospects of this development.

Hybrid propulsion systems are being tested with the aim of combining the advantages of the electric motor with those of the combustion engine. The combustion engine can be directly linked with the drive axle, or feed energy over a generator to the battery which feeds the electric motor, notably in certain areas where the system is required to operate pollution-free. During charging, the combustion engine can run at constant speed and output, thus allowing for clean operation.

In addition to hybrid propulsion systems there are systems with hybrid energy supply (e.g. from a battery and a contact line), most of which are still in the experimental stage. Among the different ways of energy supply, fuels and supply of electric power from a contact line (overhead contact wire or conductor rail) have already been mentioned. Power supply from a contact line limits the flexibility of routing; at the same time it is desirable to maintain this flexibility (e. g. for buses) by using electric motors which in turn establish the need for energy storage systems. They can be broken down into:

I. mechanical stores
  - spring
  - flywheel
  - gas pressure

II. thermal energy storage systems (= thermal unit of fuels)

III. electric stores
  - electro-chemical
    - primary elements
    - accumulators
    - high temperature secondary elements
    - fuel cells
  - electrostatic
  - electromagnetic

The main problem of currently used storage systems is their low energy density in relation to fuel (gasoline: ca. 10 kWh of usable energy per liter). Most of them reach only a small proportion of this output. Mechanical stores are only interesting as short-term stores in the form of flywheels. Already before World War II, experiments were made with flywheel drives, the so-called gyro-drives (by Oerlikon/Switzerland). Today they are being tested on buses and short-distance transport power cars (e.g. two underground vehicles of the New York Transport Authority). Among electric storage systems, only the electrochemical stores are of any importance. Primary elements are of no interest as they do not allow for multiple charges. Other electrochemical storage systems have to be left out of consideration, because

- they are too sensitive to changes in temperature,
- the basic materials are too expensive and not available in sufficient quantities,
- of excessive weight, due to the necessary amount of insulation,
- of problems (short circuits) occurring after a few load cycles.

A considerable amount of research and development is still needed before the use of vehicles with electric stores, fed exclusively or primarily by a battery, can be considered an economic proposition for short-distance transport.

For non-stored energy the following factors are of importance:

- nature of energy supplied (d c or a c current).
- length of the supply sections (depending among other things on load of line section),
- design of sub-stations etc.

Usually, the power collector sweeps the lower part of the live rail, in some cases laterally. Sometimes a second overhead wire (trolley bus) or a special rail (rubber wheel running unit or contactless support technique) are required for return of traction current. Linear motor drive systems require triple-pole rails for power supply. The risk of short-circuits increases with the number of parallel running rails, due to animals, objects, or defective power collectors.

Other drive related problems arise from power transmission (gear) and control systems.

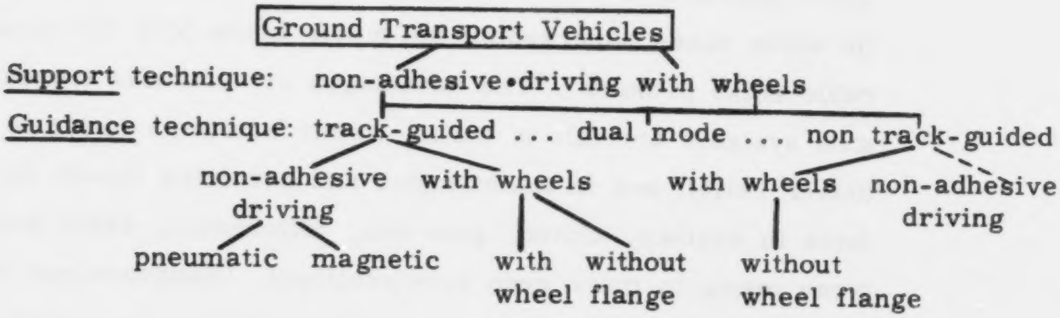
There is a growing trend towards replacing gear change drives in buses by automatic transmission for the benefit of the driver and for improved passenger comfort. Modern automatic gears have a built-in retarder or a transmission brake (in some cases superseding the motor brake with its considerable noise problem). The advantages of automatic transmission systems are felt in traffic (fewer accidents owing to driver relief) and in maintenance and servicing (fewer defects in engines, clutch, gear box, differential, axles and tyres owing to more even accelerations). Disadvantages are its slightly higher energy consumption and heavier weight.

In the field of control devices, there is a trend towards substituting electronic control systems for the proved contactors and camshaft gears. Semi-conductor techniques are already widely applied in all control areas as speed governor, shunt chopper, non-skid and non-slip devices, dead man device and control of electric brake. Merits of the shunt chopper (electronic controls in the medium and high-voltage circuits) are: avoidance of step function of current and traction when successively running the individual resistance steps, thus enabling maximum utilisation of the adhesive friction.

3.4.2. Support and Guidance Technique

Support and guidance techniques are to some extent determined by guideway and switch design.

The following chart illustrates the hierarchy of support and guidance techniques for ground transport vehicles.


Ground Transport Vehicles
Support technique:
non-adhesive driving
with wheels
Guidance technique:
track-guided
... dual mode ...
non track-guided
non-adhesive driving
with wheels
with wheels
non-adhesive driving
pneumatic
magnetic
with wheel flange
without wheel flange
without wheel flange

Support technique

The support technique is the technical solution enabling the vehicle weight to be transferred to the guideway. Until now, the following systems have been in application (most of the contactless techniques are still in the development or experimental stage):

1. wheel technique	- rubber wheels - steel wheels - multiple materials wheels
2. levitation technique	- air cushion (positive or negative air cushion) - magnetic cushion

Wheel technique

Improvements in the field of rubber-tyred wheels relate to safety, economy and riding comfort. Radial ply tyres are more and more prevailing over cross ply tyres because of the following advantages:

- less running resistance (energy saving),
- less tread wear (high mileages),
- better road adhesion.

Advantages of the cross ply tyre:

- less sensitivity of tyre walls to damage (especially important for vehicle with frequent kerb contact),
- greater lateral stiffness,
- direct steering reaction,
- better self-attenuation and greater absorbing power.

New material compositions and different tyre profiles are tested with a view to improving adhesive friction and thus safety and reliability (starting and braking power).

Smaller tyres (small cross sections) help to reduce height differences for boarding and alighting and to dispense with bulky paddle-boxes in the vehicle compartment (thus providing for a better seat arrangement). However, there is a lower limit for the size of tyres as small tyres mean less riding comfort (they reflect every irregularity of the road surface), higher wear and tear and inadequate transmission of the driving force onto the road.

Pneumatic tyred wheels running on a separate right-of-way have to meet different requirements than tyres of motor vehicles running on public roads.

The combination of pneumatic tyres on steel wheels presents a number of problems already dealt with in chapter 2.2.2.1..

In the field of steel wheels, there are integral (monobloc) wheels or wheel discs with running treads (bandages fitted by shrinking). The latter score the following advantages:

- worn flanges can be replaced easily and at little expense,
- aluminium wheel discs are used for the purpose of reducing undamped weights,
- rubber-spring elements between the wheel disc and the bandage improve the cushioning capacity and reduce running noise.

On the other hand, wheels with tyres have a safety problem as accidents can result from

- tyre breaking,
- heating (= expansion) caused by the shoe brakes, and subsequent loss of tyre.

For experimental purposes, steel wheels for new transport systems are fitted with plastic bandages to test their noise reduction capacity.

All vehicles using wheel support require a suspension system consisting of several damping elements for better riding comfort and to avoid transmission of road irregularities onto the vehicle. Transport systems using levitation techniques require only a secondary suspension system.

Levitation technique

By means of magnetic or pneumatic forces, vehicles can be supported non-adhesively (levitated). This method of levitation has the following advantages:

- no rolling resistance,
- no wear and tear at supporting elements,
- it may mitigate some noise problems,
- only secondary suspension required,
- easy on the guideway and vehicle parts.

The disadvantages of contactless support techniques are
- great amount of energy needed for levitation;
- transmission of driving force with low energy conversion efficiency
- requirement for an emergency support system.

It appears that levitation techniques are better suited for long-distance transport.

Guidance technique

Vehicle guidance can be effected by support wheels (steering, steel wheel with wheel flange) or by special guide wheels which, shored against guide walls, guide the vehicle by physical means. Unconventional track-guided transport systems use mostly special guide wheels. This functional division between support and guidance technique has the following advantages:
- each component can be optimized separately;
- static friction coefficients of the track are not used for lateral guidance;
- vehicles cannot swerve sideways (slippery surface) and are protected against derailment.

Negative aspects:
- additional components required for vehicle guidance, both on vehicle and guideway;
- more complicated design of switch points and junctions.

For combined support/guide wheels there are four different methods of steering:

- by the driver (steering wheel of the motor vehicle);
- by a central computer transmitting the steering command to the vehicle by means of wayside conductors;
- by comparison of the required and the actual position of the vehicle in relation to a guide cable in the guideway (inductive coupling);
- by means of feeler rolls on the vehicle picking up the information on the required vehicle position from tracer elements in the sides or the centre of the guideway (also below the guideway).

These methods are particularly suited for dual mode systems. Positive vehicle guidance (compulsory guidance by physical means) causes considerable wear and tear of the guide wheels due to rolling friction. Tyre wear is even increased if the vehicle deflects in transverse direction of travel. For smooth running, those systems require further development of their guidance equipments on the vehicle (e.g. size and material of wheels, damping system), and the guideway (e.g. material and design of lateral walls, switch design).

3.4.3. Transport Unit

The size of the passenger compartment is one of the factors determining maximum transport capacity and of great importance for the overall assessment of a transportation system.

The problem of an economically optium vehicle size is closely linked with two sub-objectives:

- reduction of mileage-related costs,
- reduction of vehicle-related operating costs

and can only be solved when considering the following factors:

- the necessary capacity, required by demand and network structure,
- traffic planning objectives,
- requirements of town planning,
- technical requirements.

Since vehicle size can only be optimized for a given application, the following chapter will be concerned with

- design,
- safety (passive), and
- maintenance and servicing.

Vehicle weight is an important criterion determining resistance to forward motion, and therefore also motive power, acceleration and deceleration capability and guideway usage. Excessive deadweight is avoided, wherever possible, through lighter but more costly materials and improved designs (self-supporting vehicle bodies, sandwich construction). This affects the costs of

- manufacturing (nature and preparation of materials),
- maintenance (repair times and costs),
- operation (energy consumption, relationship between payload and overall weight or transport speed).

Today, the most commonly used materials are steel, synthetic materials and aluminium. The main reasons for the widespread use of steel in vehicle construction are the high strength and good manufacturing properties, as well as the relatively favourable price. Negative are the high specific weight of steel and the necessary amount of protection against corrosion. Synthetic materials are not only weather resistant and relatively carefree, their special merits are light weight, elasticity and good vibration absorbing qualities. Because of manufacturing problems and their low modulus of elasticity (= low stiffness) their use is generally limited to a small number of vehicle components. Combinations of materials - especially combinations with steel frames - will open up a wide range of applications for fibre glass reinforced synthetic materials. It may further be expected that in the future, new aluminium alloys with high strength will find wider application in the field of short-distance transport technology.

This would, in a number of cases, permit to substitute welding for the more labour-intensive rivetting techniques (used in conventional aluminium light weight construction).

Development of suitable combinations of materials and a suitable method of light weight construction (e.g. monocoque construction) will allow for low-cost vehicle body construction. Structural units should be standardized wherever possible, in the interest of low manufacturing and maintenance costs.

Passive safety relates to all indirect measures on the vehicle designed to avoid or to reduce shock loads. There are two different types of shocks to be considered:

- the shunting impact or operational impact at low speeds (up to 15 kmh), which must not result in a permanent deformation of the vehicle involved;
- the impact resulting from an accident at higher speeds. In this case a permanent deformation cannot always be avoided, or may even be desirable in the interest of passenger protection.

As a general rule, head-on collisions, i.e. simple frontal impacts should not result in any vehicle damage. For this purpose, bumpers are designed to resist impact forces at normal impact speeds.

Protective measures to reduce the consequences of accident impacts are:

- limitation of maximum vehicle deceleration when colliding with an obstacle (buffer or crush zone),
- reduction of the hazards caused by the interior design of passenger compartments (hand rails, safety belts, head rests, use of unsplinterable materials),
- fire protection (use of fire-resistant materials),
- design of vehicle with regard to those vehicles with which a collision might occur.

3.4.4. Guideway

The guideway takes the forces resulting from the vehicle in longitudinal, transverse and vertical direction of the vehicle axle, and transmits them to the earth. Non-track guided vehicles generally use public roads. No special base courses are necessary for these short-distance transport systems as roads are also used by other heavy utility vehicles. In the field of road pavement construction, efforts are made to ensure

- high resistance to wear,
- high skid resistance (also for wet road surfaces),
- great accuracy,

as well as to develop clearly visible and wear resistant road markings.

In the field of road engineering, i.e. concrete and bituminous pavements, there are developments favouring the use of synthetic materials, wear resistant waste materials and self-reflecting building materials for pavements.

Conventional railway track engineering uses a ballast bed on which wooden or concrete sleepers form the support for the steel rail. The thermal stress exerted by the generally long-welded steel rails is absorbed by the rail rust. Merits of rails without expansion joints are:

- reduced construction costs,
- savings in maintenance costs,
- fewer railbonds,
- longer life,
- prevention of rail shifting,
- increased riding comfort,
- reduced impact stress on permanent way,
- savings in tractive energy.

The great depth and weight of ballast has favoured the development of ballast-free track engineering especially on bridges and in tunnels. Another positive factor contributing to its more and more wide-spread application is the low maintenance and servicing requirement. It may be assumed that in the long-term perspective, the high construction costs of ballast-free tracks can be reduced through rationalisation and more frequent application of this construction method. The development in the field of ballast-free tracks is pursuing the following objectives:

- lowering of the solid-borne and air-borne sound levels,
- garanteed position stability of the track,
- simple, fast but accurate placing and laying techniques,
- capability of height and lateral adjustment,
- reduction of maintenance requirements for tracks and switches,
- lowering of construction costs.

Most unconventional track-guided transport systems are horizontally and vertically supported by separate guideway elements. The nature of the shocks to be absorbed is of great importance as they can result in unsteady running characteristics. When developing guideway girders, special regard should be given to a relatively low sensitivity to climatic conditions and high wear resistance.

Guideways to be used for levitated techniques are still in the experimental stage. They have to meet special requirements with respect to accuracy and design. In the event of sudden failure of the levitation system, the release of the emergency support unit produces longitudinal forces which have to be absorbed by the guideway and the track girder.

3.4.5. Switches

All conventional rail systems engaged in short-distance traffic use active switches. Vehicle guidance is effected by switch blades resting on slide chairs. Apart from the horizontally moving guard rail system, there are systems with a vertically lower-able guard rail (e.g. the rubber-tyred Metro system at Sapporo has a central guard rail which can be lowered). The active switch system has a number of disadvantages:

- high maintenance requirements,
- high probability of failure,
- slowing down of operation (reversing time and in some cases slowing down at switches),
- incident on smooth running,
- noise problem.

Because of the difficulties connected with active switches, such as long reversing times, the Alweg system has not been able to achieve more wide-spread application.

The development of different guidance techniques has resulted in switch designs which eliminate some of the above mentioned disadvantages. Passive switches consist of fixed elements only; the track-installed guide-elements in the switch area exists on only one side of any direction and the vehicle is guided in the switch area by vehicle-mounted auxiliary elements.
Passive switches are necessary, to realize short headways and a high system capacity of small cabin systems as the reversing time of an active switch lengthen the distance between two cabins.

Failures occuring during the passing of passive switches are mostly caused by vehicle defects, whereas active switches are often themselves the cause of failures. Break-downs in systems with passive switches - without moving parts - can be removed more easily by withdrawing the defective vehicle. The functioning of fixed switches can generally be monitored more easily and garantees greater safety than vehicle mounted switch elements. So the lower maintenance required for the fixed switch elements in the track is offset by the higher maintenance requirement for the vehicle-mounted switch elements.

3.4.6. Brakes

The safety of a vehicle is primarily linked with the reliability of its brakes which in turn is determined by
- the deceleration characteristics of its braking system,
- its failure rate,
- and its sensitivity to climatic conditions.

Conventional short-distance transport systems are fitted with adhesive brakes (fiction brakes, generator or motor brakes) or non-adhesive brakes (magnetic rail brakes).

Road vehicles are more and more equipped with disk brakes which have the following advantages over drum brakes:

- they lose less braking power at higher speeds,
- easier change of brake linings,
- reduction of maintenance costs (is not unlimited, since depending on the typs of construktion and the necessity of adjusting the disks)

A very important factor for traffic safety is load-insensitive braking combined with an anti-blocking system. In order to avoid wheel-blocking through braking, the braking power must be spread on the individual axles in proportion to the actual dynamic axle load; this distribution of the braking power must be a function of the relationship between full load and empty load (for buses: 2 : 1; trucks: 10 : 1), of load spreading, and of deceleration under the influence of braking. A more sophisticated anti-blocking system is particularly useful for wet roads or uneven wheel adhesion, it controls the different speeds at which the wheels turn and effects the appropriate distribution of the braking power at optimum efficiency.

In recent years, wearfree motor brakes have been a legal requirement for utility vehicles with a total weight above 9 tons in a number of European countries, such as FRG, Austria and Switzerland [37]. So far, this function has been largely fulfilled by the low-cost motor exhaust brake. However, in recent years, efficient electric and hydraulic motor brakes have been developed which have a number of advantages over the motor exhaust brake:

- they are much more efficient,
- they can be controlled by fine graduation.

Their disadvantages are:

- additional weight,
- at maximum revolutions, a power loss of 5 to 10 metric horse powers, not braked.

Hydrodynamic torque converters offer the possibility of integrating in the gear box an efficient braking decelerator which can operate at full motor speed.

In some countries rail vehicles are more frequently equipped with disk brakes than road vehicles. Compared with the shoe brake, where two cast iron or plastic shoes are pressed against the tread of the tyre, the disk brake has the following advantages in addition to those already mentioned earlier:

- simpler design of the braking system,
- less noise development during the braking process,
- no additional tyre wear.

On the other hand, the replacement of the brake shoes also does away with the advantage of "automatic" cleaning and roughing up of the wheel tread which improves adhesion.

In addition to the brake acting on the wheels, rail vehicles are fitted with magnetic rail brakes which permit stronger deceleration without additional utilisation of the friction between rail and wheel. A side-effect of this additional device is a slight increase of the adhesive value caused by the roughing up of the rail surface. On the other hand, the magnetic rail brake also involves certain accident risks: when passing over switches or negotiating narrow curves,. the magnet can get caught at the switch blades or the check rails.

The use of magnetic rail brakes in connection with fully automated operation must be combined with a quickly responsive and reliably functioning anti-slide device.

In France a new type of brake was developed for rail systems [42]: electric currents generate inductive forces which act on the wheels and the rails. If slipping occurs (fewer wheel revolutions) the productive forces act mainly on the rails thus producing a desirable effect for rail systems, i. e. non-adhesive braking.

Another type of brake for electrically driven rail vehicles is the electro-dynamic (motor) brake. The energy produced is either converted in rheostats into heat or returned to the network. This further development of thyristor d c regulator technology has brought the following advantages for deceleration:

- infinitely variable braking force (more comfort),
- shorter braking distances due to shorter sliding paths (more safety),
- reduced size of rheostats,
- less wear on other vehicle components,
- energy saving through regenerative braking,
- less heat development in tunnels.

The shorter duration of the sliding process lessens the load on the road bed, and the wear on wheels (wheel flats) and rails. The greater accuracy of braking made possible by infinitely variable control and quicker braking response can be used for automatic target braking.

Levitated vehicles in most cases are fitted with non-adhesive brakes and additional friction brakes which reduce vehicle speed to stopping point by means of skids and clasps, thus serving as stopping brake at stations and as emergency brake.

3.4.7. Stops/Stations, Method of Weaving (Capacity)

With track-guided transport systems, boarding and alighting of passengers can take place on the main track or on a parallel side track. Vehicles standing on an off-line track can be overtaken by others, thus providing the possibility for directly routed traffic (without intermediate stops at each station) operated with relatively small vehicle units. On-line stations which are the general rule with present short-distance transport systems do not permit passing or overtaking by other vehicles. Stops at each station produce a great discrepancy between maximum vehicle speed and actual transit and turnround speeds.

Where frequency of service is low, great transport demands can only be handled by means of big vehicle units.

A key element for the capacity of a transport system is its method of merging two or more traffic streams. It is necessary to distinguish between

- systems operating at variable speeds in the weaving section, and
- systems operating at constant speeds (synchronous drive).

Maximum capacity of the weaving section can be achieved if the vehicles (or platoon of vehicles) can move at different speeds. In this case, vehicles must be decelerated (or accelerated) to optimum speed producing maximum line capacity.

3.4.8. Networks

In geometric terms, networks can be broken down into the following categories:

- grid
    - simple rectangular or circular grid
    - interconnected grids with loops
- radial network
    - ramified network
    - interconnected radial networks
- combinations.

Good area coverage is achieved by interconnected grids (e.g. bus systems). Rapid transit railways usually operate radial networks, i.e. they serve existing development axes. Tramway networks are not so easily classified as they can also cover wider areas, owing to their capacity and relatively low infrastructure costs. New transport systems tend to be designed for a specific type of network determined either by the operating concept or their capacity.

Of great advantage for users and operators alike is scheduled fixed route operation on interconnected radial networks, with a high proportion of directly routed non-stop services.

User advantage:

- short waiting times (on the common section of several lines, each train can be used up to the separation of the lines)
- great operational reliability through time table compliance and lack of interference from other areas;
- simple information owing to clear route pattern.

Operator advantages:

- high capacity
- economic operation,
- low construction cost (junctions),
- simple turn-round plans, duty rosters and time-tables.

Disadvantages can be minimized by means of the following measures:

- transfers on the same platform,
- good time-table coordination,
- for less important transfer relations, platforms at different levels.

The sight configuration of a network for a certain application is depending on the structur of the city and the most important transportation relations. Cities having a historical city-center and a radial street structur offer other prerequisites as a planned city with a rectangular street structure.

3.4.9. Operating Concept

Short-distance transport services can be provided in two different forms:

1. as regular services (e.g. according to a fixed time-table)
2. as services provided upon "request".

Depending on daytime and demand, these two forms of service can alternate (e.g. during peak hour traffic: according to time-table; during off-peak hours: upon demand).

Regular services:

Conventional transport systems normally operate on specially approved routes and according to a fixed time-table. Adaptation to demand is achieved, on a long-term basis, by modification of the time-table, and on a short-term basis, with a certain "time-lag". In the event of unexpectedly high demand at a stop or station, passengers have to put up with waiting times. Operators can avoid these inconveniences by

- keeping depots at specific points in the network, where vehicles can be made available at any time,
- increasing service capacity on a short-term basis (by coupling together vehicle units).

Demand operation

The availability of directly routed, demand-operated services enhances the attractiveness of public transport. Passengers can start their journey at any time (except perhaps in extreme traffic situations, e.g. rush-hour). Compared with scheduled services, transit times can be reduced as a less number of stops have to be served and there is no need for transfers. Demand fluctuations are matched by a corresponding supply, as vehicles are only operated on demand. Whereas scheduled services have to be operated with bigger vehicles, demand services may be more usefully provided by smaller units, which however push up investment and operating costs for the operator.

3.4.10 Operations Control

Operations control covers operation, its monitoring and control, and the necessary software. For automated transport systems, the software consists of programme modules doing or facilitating the tasks of drivers or dispatchers, e.g. switching, empty runs, modes of operation, vehicle coupling, measures in case of failure or break-down.

System software is determined by certain system parameters, such as the headway control technique. With tramways, buses and taxis which use the traffic space of public roads, driver sight is the factor determining braking distances and therefore vehicle headways.

With rail systems running on a separate or exclusive right-of-way, vehicle headways can be a function of the signal distances, i.e. of predetermined blocks. The use of a time and/or distance-related system of data recording and transmission, for instance, by means of wayside conductors leads to shorter vehicle headways. But since idle periods may continue to exit (information limited to certain time intervals, no transmission of messages), the ultimate objective is a continuous process of data gathering, recording and transmission.

Apart from the above mentioned method of headway control there is, also, for cabin systems, the moving block or moving slot system. The latter is characterized by the fact that at a given time vehicles can only be at a precisely determined point in the network. They cannot leave an off-line station unless they can switch into the main traffic stream at exactly (in terms of time and space) the assigned free spot in the moving slot. However this may lead to delayed departures and vehicle queues in the off-line station.

Delayed departure and therefore longer stopping times in off-line stations may also occur with different operations control concepts - unless they make allowance for vehicles slowing down and queuing up on the through track. Systems with synchronous drives do not permit acceleration or braking on the through track (except in an emergency) and therefore no queuing up of vehicles.

Operations control systems require equipment for passenger handling, crew and track personnel, technical personnel and dispatch, such as

- information and passenger handling systems

- communication systems (radio, telephone, television)
- passenger counting and vehicle monitoring systems
- quick-response signalling systems for failures and repair
- computers.

Depending on the functions which it is required to perform, operations control equipment can be broken down into the following functional categories:

- monitoring
- operations
- safety
- vehicle control)
- network control) frequently combined.

Automated systems, but to an increasing degree also conventional systems, require computers for the handling and processing of the great quantities of data involved. The existence of different systems of operations control constitutes a great handicap for standardisation, although it would be most desirable for cost reasons.

In the field of electronic control equipment, regardless of whether it is computer-supported or not, there are two methods of ensuring the safety of data transmission and processing:

- through redundancy
- by means of fail-safe equipment

In order to ensure that operations control systems assisted by process computers or micro processors can meet the stringent safety standards applying, for instance, to signal cabins, stationary and vehicle-mounted electronic control equipment is provided redundantly. However, this duplication of software is not yet sufficient considering that programming mistakes cannot be identified by a simple comparison of output.

This explains the growing trend towards decentralisation of the safety control functions, i.e. dispatch messages are transmitted from various points in the network to an operations control centre. This approach provides the same measure of flexibility as a centralised system of safety control.

3.4.11 Safety Techniques

Safety is a primary concern for all transport systems. Therefore, safety and signalling equipments have to meet high standards.

The most important function of this equipment is driver relief and minimization of human failure as accident factors. With growing automation it becomes indispensable to further develop and perfect safety and signalling techniques. In addition to safety of operation which is its primary function, sophisticated and efficient safety equipment produces the following positive side-effects:

- higher system capacity through reduced headways,
- simpler operation,
- simpler traffic management,
- better riding comfort,
- shorter transit times owing to shorter stopping times at stops and signals.

With driver-operated vehicles, speed changes are effected by direct driver intervention responding to a signal, or by automatic intervention controlling operation (e.g. continuous automatic train-running control, automatic braking in case of failure to respond to signal or to press vigilance button).

Systems with automatic operation do not provide for driver intervention, except in an emergency. Operation is performed and monitored automatically. Human intervention from a control centre is normally possible; vehicle movements, routes and signals etc. are visually displayed in the control centre.

At the present time, the use of unmanned vehicles on public roads is not yet conceivable. Automatic steering systems for road vehicles have been in development and testing for some time; automatic guidance systems (e.g. parking guidance) are already in use.

Important and delicate, safety relevant components (such as brakes) have to be inspected at regular intervals. For this purpose, it is necessary to further pursue the development of diagnosis equipment.

3.4.12. Passenger Handling

Passenger handling comprises of ticket distribution and sale, cancellation and control.

Apart from the different types of fares and tickets, there are different methods of passenger handling:

Ticket sale:
- by personnel at ticket office (in stops or special box offices);
- by personnel in the vehicle;
- by machines.

Cashless ticket sale:
- mailing of tickets or stamps and debiting the account with equal monthly amounts;
- issue of coded tickets and debiting the account with amounts relating to the use of system by the ticket holder.

The latter method is not yet put into practice but its experimental use in the near future is possible.

Ticket cancellation:

- outside the vehicle by machines
  - combined with the vehicle demand
  - without effect on operation
- inside the vehicle
  - by machines
  - by ticket-inspector
- no need for ticket cancellation.

Ticket inspection can take place on a spot check basis, in connection with ticket cancellation by the operating personnel or at barrier gates.

Ticket vending machines are becoming more and more common as a method of saving ticket personnel and of increasing transit speed. It may be expected that in the future, new automated transport systems will combine ticket-sale from the machine with vehicle demand, destination coding and ticket cancellation. However, ticket-sale by machines also involves a certain number of drawbacks for passengers:

- most machines only accept coins,
- some machines do not return change,
- handling of some machines requires a fairly high standard of intelligence (i. e. understanding of the fare structure);

for operators:

- susceptibility to failure,
- risks of theft and high repair costs,
- susceptible to deliberate destruction,
- problem of space requirement; along public roads additional problems of electric connection and protection against atmospheric conditions;
- requirement for daily maintenance: Withdrawal of till box and refilling of certain coins for change.

With growing use of ticket machines, it will be necessary to provide some system of information at stops/stations for the benefit of users. The presence of personnel can provide this information in addition to preventing possible destruction and theft and providing passenger protection against harrassment and criminal acts.

Ticket sale by the driver (e.g. buses) involves the risk of reducing transit speeds: operation can be upset by a great number of passengers trying to board (delays at stops). Although the driver can give information, it is often unsatisfactory for the passenger, because of other duties requiring the driver's attention.

4. Conclusions

4.1 Trends in System Costs

4.1.0 Preliminary Remarks

One of the most important, and in many cases the decisive factor tipping the scale in favour of or against the realisation of a short-distance transport system is system costs. In a relatively broad and general study as this one, it is hardly possible to arrive at universally applicable conclusions about system costs, because costs can only be accurately determined for actual applications i.e. an actual system to be built in an actual town. On the other hand, this study would not be complete if it did not attempt to give some indication of the cost implications of individual systems. This will be attempted in the following chapters.

In 1974, a comparative study of "Existing and Future Short-distance Transport Systems" was completed in the Federal Republic of Germany [14]. The systems considered were assigned to specific applications considered to be typical of the systems concerned (in terms of transport functions), in order to preclude meaningless applications. Costs were determined in relation to service provided (in terms of Pfennings per passenger-km). This approach was used to show how much a passenger would have to pay per km of travel if the system were to cover its costs from fare revenue. The study was based on the hypothesis that all systems considered were operational, therefore, problems of "running-in" a system were not included. Another important assumption was that costs of fixed assets, i.e. the purchase price had to be calculated at an 8% p.a. interest rate for costing, or in other words, it was assumed that fixed assets were financed from borrowed funds. Furthermore, a number of important cost items (i.e. land purchase, system software) were not considered as they could not be estimated. This aspect will be specially covered in chapters 4.1.2.1 and 4.1.2.2.

Bearing in mind the above qualification, the results of the German study can summarized as follows:

4.1.1 Results of a German Study

4.1.1.1 Level and Structure of System Costs

For new systems in nearly all applications, the level of costs (amount of costs per passenger-km) was higher than for conventional systems. In some cases, cost differences varied by a factor of 10. With conventional systems in the same application, the cost level differences were in the order of 10%.

With respect to cost structure, the study indicated that generally all new systems entail heavy fixed investment (investment/operating costs > 1).

Conventional large-capacity systems operating on a separate right-of-way (tramways and rapid transit railways) also require a high proportion of fixed investments. Bus systems, in particular dial-a-bus systems, incur by their very nature high operating expenses; on the other hand they have to pay nothing or very little for their right-of-way. This trend does not change when assuming a high proportion of separate bus lanes for bus systems.

4.1.1.2 Investment Costs

Capital investments were broken down into investments for:

- track
- depots, maintenance and cleaning plants
- vehicles

Track costs (as total costs) are independent of the traffic volume provided. In terms of costs per passenger-km, they are determined by technological requirements (level of total costs) as well as by the type of service to be provided (level of traffic-related costs). As the traffic volume increases, the costs per passenger-km decrease.

The study indicated that for all new systems with a separate right-of-way - involving among other things a considerable technological effort - capital costs for tracks per passenger-km are high or very high, the main reason being, that new systems, in general, are not designed for high handling capacities. This is particularly true of small cabin systems and "small" large-cabin systems, where it is not possible to distribute high capital costs for the track over a great volume of traffic.
This trend is even intensified if distances between stops or stations are relatively short.

Conventional track-guided large-capacity systems also require investment in track infrastructure, but this has no negative consequence owing to the great volume of traffic carried by these systems. However, costs per passenger-km grow higher where a great proportion of the network is in tunnels.

The bus using the right-of way of public roads is a costwise favourable system even at low volume of traffic and short distances between stops. Under the aspect of track costs, dial-a-bus systems have to be rated more or less like buses, whereas dual-mode-systems are more in the nature of new transport systems.

The capital costs for depots, maintenance and cleaning plants are to a large degree determined by the number of cabins in operation. Under this aspect, small cabin systems and "small" large-cabin systems have to be given a lower rating than systems with large-capacity cabins.

With the new systems considered in the study, another element had to be included: unlike conventional track-guided systems or buses, new systems also require technologically more sophisticated tracks in their depots.

For vehicles too, costs per passenger-km vary. Thereare three influencing factors: First, it is a generally accepted fact that the life of vehicles determines vehicle costs; in other words, it is not desirable to run short-lived and expensive vehicles (as some new systems considered turned out to do).

The second important factor is vehicle holding capacity: Under this aspect small cabin systems can only be of interest if their cabins can be manufactured at extremely low costs, as the installation of a great number of technical equipments in a great number of cabins would result in prohibitive costs.

Third factor is vehicle utilisation in traffic and operation, i.e. in particular such data as turn-round speeds, peak traffic demands, and daily load factors: these data have a considerable impact on the number of vehicles required. Seen from this viewpoint, one would give preference to medium-sized vehicles, capable for coupling and a high turn-round speed.

In a very simplified way, the following order can be established on the basis of vehicle costs per passenger-km, beginning with the highest cost level:

1. new systems
   (relatively small, usually technically sophisticated and relatively short-lived cabins);
2. conventional large-capacity systems
   (large vehicles, sometimes technically sophisticated but relatively long-lived)
3. buses
   (medium-sized vehicles, non-sophisticated, relatively short-lived).

4.1.1.3 Operating Costs

When considering the costs of traffic personnel, a distinction must be made between that proportion of the traffic personnel that can, and the other that cannot, be related to the volume of traffic handled.

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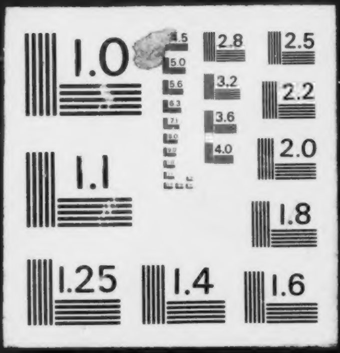
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2.2
2.0
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1.8
1.25
1.4
1.6

New, automatically operating systems only have stationary traffic personnel, i. e. that cannot be related to the volume of traffic carried (operation and monitoring of control centre, tracks and stations). Dial-a-bus and dual-mode-systems require both stationary and crew personnel, the latter representing the major part of the traffic personnel.

Similar conditions apply to conventional systems like buses and tramways. Underground and rapid transit railways also require stationary and crew personnel, but the latter's proportion amounts to only one third of the traffic personnel, due to the personnel needed for stations, switch towers, supervision and ticket control (functions performed by stationary personnel).

Costs of stationary personnel are determined by the traffic volume and the nature of the network in terms of equipment (stations, control centre etc), whereas the costs of crew personnel are a function of the personnel requirement per cabin and the number of cabins operated. Consequently, the costs per passenger-km of crew personnel remain constant for all applications, provided that the daily load factors and the number of coupled units in the system remain unchanged.

High costs result for dial-a-bus and dual-mode systems from the fact that both systems have a relatively high crew personnel requirement per unit and that their vehicles have a low carrying capacity thus increasing the number of vehicles needed.

Concerning the costs of the technical personnel, basically the same factors apply as for traffic personnel. A breakdown of systems according to their proportions of technical personnel that can be related or cannot be related to the volume of traffic handled produces the following picture: The costs of "stationary" technical personnel of new and conventional systems - with the exception of tramways and bus systems - represent between 35 and 50% (of the total cost of technical personnel). For tramways and buses, "stationary" technical personnel account for only 10% of the total costs of technical personnel.

All automated systems i.e. operating without drivers, have higher and in some cases considerably higher costs per passenger-km for traffic and technical personnel than their non-automated rivals.

In the conditions assumed for the purposes of the study, it is not possible to conclude that automation necessarily leads to personnel savings. Where it has been possible to reduce traffic personnel, these savings were more than offset by the costs of the technical personnel.

Not enough experience being available about the personnel requirements of new systems, it was necessary to proceed on assumptions. Therefore, it cannot be excluded that the above results on personnel costs are determined by the premises. The personnel estimates for new systems were made on the basis of experience available with conventional systems (e.g. possible requirements for stations, cleaning personnel, maintenance and servicing personnel); in case of doubt, they were calculated in favour of the new systems. Actual applications of new systems will have to prove if their requirements differ from (i.e. remain below) the above values.

Energy costs of systems can be clearly broken down according to their determining factors. Station energy costs are independent of the volume of traffic handled; energy consumption is primarily determined by station equipment such as escalators etc. The level of costs per passenger-km is a function of the volume of traffic handled in a given application, distance between stops and equipment of stations with escalators.

As escalators and other pedestrian aids (lifts, passenger conveyors) have a direct effect on the energy costs of stations, costs can also be attributed to the amount of height differences to be overcome in a station or stop area.

Traction energy requirements and therefore costs depend on technical and operational system characteristics and the volume of traffic.

The sequence of vehicle operations from start to standstill (hence also the distance between stations), the operating concept (demand operation or conventional scheduled traffic and their effects on the daily load factor pattern), type of propulsion and vehicle weight are some of the technical and operational characteristics that determine the energy consumption. The traffic volume influences the absolut size of the energy consumption through the weight of the passengers or the frequency of the stops (request stop) and as a quotient the relative size of the specific energy consumptions.

Energy costs account for a comparatively small proportion of the operating costs. Rapid transit systems and all bus systems do particularly well (down to 7% of the operating costs) due to the lack or very low energy requirements for stops. Energy costs of other systems score a share of about 10% in the operating costs. This means that systems do not react with particular sensitivity to variations in the energy price sector. But it also implies that major saving of energy costs can only be achieved in exceptional cases.

Maintenance and servicing costs consist of material costs for mobile assets (vehicles) and material costs for fixed assets. With traditional systems, these costs are relatively low, both in absolute and percentage figures with their maximum share in the operating costs amounting to 17%. Systems with a small proportion of fixed assets (buses and rapid transit systems) show nearly constant maintenance costs, regardless of application.

Similar to the procedure applied for personnel costs, it was necessary to proceed on certain assumptions due to the lack of sufficient empirical data on maintenance and servicing costs of new systems. With a large measure of agreement from manufacturers of new systems, the study chose the following estimates for material costs:

7.5% of the cabin cost for vehicle material;
0.8% of the price paid for fixed assets for maintenance and servicing, as far as elevated systems are concerned.

So, material costs are mainly influenced by the requirement for fixed investments and the prices for cabins and fixed assets.

4.1.2 Further Aspects

4.1.2.1 Other Cost Items to be Considered

Planning Costs

In addition to capital costs which can be broken down into
- building costs (shell construction, interior work, wainscoting, purchase price of land, construction-related costs like road building, laying of cables, and where applicable, of track);
- equipment costs (signalling and safety equipment, sites for passenger access, exit and transit, vehicle fleet and vehicle maintenance and servicing plants),

consideration has to be given also to planning costs. They are determined by the technology used and the level of track construction (elevated, surface level or underground). For rapid transit rail systems, it is estimated that planning costs represent about 5% of the building costs and about 10% of the equipment costs. Difficulties developing in the course of the plan acceptance proceedings, such as political resistance or public protests, tend to increase these percentages. Resistance is particularly likely in the case of elevated systems.

Land Purchase and Clearance Costs

In the interest of system efficiency and public acceptance, system rights-of-way should be established with a minimum disturbance of other activities, public or private, and with maximum respect for the environmental and land use objectives.

In view of constantly increasing land transfer and clearance costs, it is recommended to proceed in the following order when planning and constructing system rights-of-way:

1. recording of a public charge on the land, i. e. limitation of real estate usage (compensation paid in cash);
2. compensation paid for demolition of buildings on the real estate, but no purchase of the land;
3. purchase of real estate, including buildings.

It is impossible to venture a meaningful generalized estimate of the land purchase costs of any new or conventional short-distance transport system. The costs are almost exclusively determined by the conditions prevailing in each individual case so that any assumption is bound to be arbitrary and to falsify the results. Non-inclusion of land purchase cost affects different systems differently, favouring those with a great requirement for land purchase. However, other than the fact that systems requiring much land are more expensive than others, no further statement of general applicability can be made.

As a matter of principle, land purchase cost must be given special consideration when deciding on a system for a given application. These data can help to establish an order of preference among several alternative systems. It may also happen that land purchase costs do not affect the order of preference for a specific application.

Construction-related costs

Before and after the actual construction work, certain expenses arise which are nearly proportional to the total building costs. These expenses become necessary for

- wiring, sewage, etc.
- road construction work and landscaping (including traffic lights and public lighting),
- preparatory and follow-up work (expert opinions, examination of building plot and ground water, materials testing, measurements),
- other material expenses.

Experience has shown that in most cases these costs are not considered in connection with capital costs. Therefore, it appears necessary to emphasize their importance. According to the SNV study, construction-related costs amount to between 7 and 15% of the total construction costs; the study included in its estimate guideways in cuttings and tunnels, as well as 20% shield tunnelling. Whereas in absolute terms capital costs of small cabin systems are lower than for rapid transit systems, the percentage of construction-related costs is higher. For elevated systems construction-related costs are lower than for systems built in a cutting or tunnel.

Software costs

A second problem, but which concerns only automated systems, is software. In this context, the term shall be understood to include all systems where operation is primarily computer controlled.

The installation of an automated system involves, similar to capital costs, costs for the development of the software. Furthermore, there are software maintenance costs, arising in connection with operation. Both cost elements vary from case to case. It might also be that frequent operation of a system produces know-how on the development and maintenance of its software, thus reducing the costs of subsequently installed systems. But as there is no experience available with software costs, their non-inclusion has the same effect as with land purchase costs.

Safety costs

In many countries, legislation requires the provision of an emergency space along the tracks. The emergency space serves for the purpose of maintenance and servicing work along the track as well as for track surveillance and inspection, for the escape and rescue of passengers in case of accidents and break-downs, etc. Provisions concerning the availability of an emergency space are usually independent of the technological concept of a system. For unconventional systems which are not yet put into practice, the requirement causes the following problems:

For systems running at surface level or in tunnels, the provision of an emergency escape route does not present any technical problems and therefore the resulting costs can be determined without difficulty. However, for elevated systems, the requirement that passengers must be able to be rescued at any time and from any point along the track, does present a technical problem.

Existing unconventional elevated systems - in particular suspended systems - have developed individual concepts for track maintenance and passenger rescue, which vary in terms of efficiency and costs. Basically, all systems must provide the same level of safety and equal effectiveness. A suitable walkingpath for maintenance and emergencies should be provided permitting people to be rescued.

Settlement of damages/liability

It has to be distinguished between

- damages to passengers or third persons by the system
- offences or crimes against vehicles or installations of the system
- offences or crimes against passengers using the system

Although payments resulting from a liability for damages caused through the operating system constitute only a small proportion of operating expenses, it is interesting to note the differences between the various systems concerning damage payments.

Usually operators protect themselves against the often existing legal regulation for liability concerning material and personal damage by insuring themselves with insurance companies or liability associations as well as setting up their own reserve funds.

Insurance premiums and claims paid - if related to passenger accidents per km - can be kept low owing to the high standard of safety of public transport. Nevertheless, track-guided systems are perceived as constituting an additional safety hazard. The accident risk of public transport constitutes only a small fraction of the risks involved in private transport in cities (a power of ten less). This applies to the risk of being involved in an accident and of being injured or killed.

It may be realistically assumed that the safety performance of new systems will be at least as high as that of rapid transit systems, tramways and trolley buses.

Studies conducted in the FRG have shown that the risk of getting injured while using public transport is at least not higher than the risk of getting killed by a private means of transport on public roads [17] .

Criminal acts against systems installations or vehicles or passengers have to be looked upon separately but having partially a common cause: absence of operating staff and other "protecting" passengers.

According to American studies [36], there are five times more criminal acts committed in rapid transit systems than in buses. The operator is not liable for damages to passengers caused by other passengers unless the damage is related to transportation operation, e.g. the jerk of a vehicle.

A statistical record of 1971, covering 37 US and 4 Canadian transport systems indicates that the costs caused by vandalism amounted to a maximum of 1.1% of the operating costs, but on the average they were less than 0.5% [36]. In absolute figures, however, the amount of $ 2.0 million, paid by the New York Transport Authority in 1971, is quite considerable.

4.1.2.2 General Development Trends

The above mentioned SNV study permits one to draw - with all necessary caution - some relatively global conclusions concerning system costs, which will probably remain valid as long as there are no radical technological changes, or in the community's scale of values.

1. Systems operating on a separate right-of-way require high utilization if they are to keep their costs per passenger-km relatively low.

This conclusion applies regardless of whether a system operates automatically or not. This means, that in the present stage of technological development, many systems with low capacity have a cost problem because the necessary infrastructure is too "expensive". It is also questionable whether in the present and foreseeable economic situation these systems can be sufficiently subsidized by public funds in order to arrive at fares which are acceptable to the users.

Automation of large-capacity systems operating high capacities to meet high transport demands could be interesting in terms of costs as the additional costs involved are not limitative owing to the effect of quantitative degression with increasing volume of traffic.

2. Automation of low capacity systems for the purpose of personnel savings can be problematical.

Personnel costs continue to grow faster than the costs of equipment, a fact which would normally favour automated systems. But, there are at least two noteworthy counter-arguments:

First of all, automation saves only a limited proportion of less qualified personnel (e.g. station dispatchers, station surveillance personnel). At the same time automation requires additional highly qualified personnel for other functions (computer control centre, in maitenance and repair, monitoring). It is therefore, questionable, at least in some cases, whether a net saving in personnel can be achieved through automation.

Secondly, capital requirement for necessary equipment is in many cases very high. Therefore, the investment must be compensated for, before savings can result from automation. In some cases, this amortization process lasts as long as the life of important components of the automated system.

In this context, it may be justified to raise a question of a more general nature, namely whether in the long run, it can be considered meaningful to continuously push forward substitution of capital for labour in an economy where full employment can no longer be taken for granted, especially when bearing in mind that this substitution process is accompanied by a number of disadvantages, the most important being a higher rate of criminality and vandalism which may result in a drift of users to other forms of transport.

3. Under the aspect of initial costs and possible subsequent changes, new and conventional systems operating on a separate right-of-way are generally less favourable than other forms of transport.

Because of the greater technological effort involved, these systems require long construction periods during which they cannot provide any services but during which they cause expenses and usually adversely affect traffic conditions in the town concerned. Furthermore, they are less flexible with regard to subsequent changes.

Buses and dial-a-bus systems have none of these problems. Their technology is relatively simple. Exclusively from a cost point of view, there is much to be said in favour of bus systems. This does not mean that on the whole buses are particularly favourable systems. Their problems are only of a different nature (e. g. interference from private transport, very high traffic personnel requirements.)

4. 2 Some Aspects Concerning the Improvement of Public Transport

In view of the important role of public transport in solving the traffic problems of towns and cities, it is urgently recommended to make public transport systems as efficient and attractive as possible, in order to make it easier for potential users to decide in favour of public transport.

When chosing between public transport and private transport, there are a number of aspects orienting the decision in favour of private transport. But many of the advantages of the private car can prevail only as long as the number of people enjoying them at the same time is not outpacing the capacity of the highway system.

If public transport is to be a true alternative to private transport, it must be able to meet certain standards in respect of travel speed, economy and comfort which at present are met by only few public transport systems. Therefore, sustained efforts to promote public transport should be part of any policy aiming at an improvement of traffic conditions in local communities.

The following desirable goals should be considered when improving the quality of public transport:

1. Travel time from the beginning to the end of a journey (e.g. from home to work) should be equal or even shorter than travel time in the private car, especially during peak-hour traffic. This requirement pre-supposes
   - dense area coverage
   - short walking distances, especially in relation to overall transit time
   - through-routes requiring no transfers
   - short vehicle headways
   - little travel time losses due to stops or while on public roads (traffic lights, congestion).

2. Fares must be simple and clear. They should not only be determined by the principle of independent profitability but should also provide a high degree of mobility among low-income groups.

3. Before and after the journey the following aspects are noteworthy:
   - simple information, low rate of action required
   - stops and stations that can be reached without hazard or detours,
   - protection against atmospheric influences while waiting at a stop/station
   - punctual arrivals and departures (reliability of service, no unnecessary waiting times).

4. During the journey, a high standard of comfort and convenience should be provided. This includes:
   - seats, especially for longer trips, where passengers are not squeezed in or have to sit "stiff" (no pitch),
   - take-off and braking with low jerk values and acceptable acceleration values,
   - little vibration and deflection to permit passengers to read while travelling,
   - low noise values to permit good voice communication,
   - ventilation and heating/cooling (heat insulation) providing convenient climatic temperatures also under extreme traffic loads,
   - courteous and forthcoming treatment by the personnel.

For all investment decisions, both the macro- and the micro-economic effects have to be taken into account. Assistance measures which impair the economic results of transport systems have to be critically examined as to their estimated added benefit for the users or the public.

The contribution made by public transport systems towards improving the quality of life and environment can still be enhanced. For a part of the population, public transport is one of the welfare responsibilities of public authorities.

4.3 Status of and Trends in System Development

A comparison of the developments of conventional and unconventional transport systems will indicate

- that prototypes exist for only few unconventional systems
- that even fewer systems are run on test and trial plants
- that systems were put into actual operation in only limited, hand-picked applications.

This applies to the Alweg system in Tokyo-Haneda, as well as to the PRT system in Morgantown/USA, or the operation of automated cabin systems on American airports, parking areas and shopping centres. Although a constantly growing number of proposals for new-type systems were put forward between 1970 and 1973, the number of projects that had been followed up was considerably reduced by the end of 1975. Most proposals got stuck during the conceptual phase, other developments were discontinued, although prototypes or test plants were already available (e.g. the Bendix-Dashaveyor/USA project or the Krauss-Maffei/FRG project). Public funds for the development of systems including their testing and trial plants are made available in European countries for a maximum of 5, in the USA for only a few more cabin systems. By the end of 1975 some dial-a-bus systems had been given up; the same thing happened to the development of dual-mode systems (following an extensive conceptual phase in the USA).

Development costs and periods for unconventional systems depend to a high degree on the operational and technological system characteristics. Unconventional components need more time for development than conventional ones. The putting into operation of unconventional systems in the USA can be explained by the fact that they used conventional modes of operation

(scheduled services, shuttle and loop services) and existing technologies (electric rotary motors, rubber-tyred running units with support and guide wheels). The unconventional characteristics were limited to:
- the arrangement of the support and guide wheels
- the type of lateral guidance (compulsory guidance by physical means, or by adhesion),
- higher frequency of service (some operating on demand)
- driverless operation, combined with
- an altogether high degree of automation.

It is interesting to note that no more than one unconventional system for directly routed, non-stop operation was developed in each country.

75% of all new developments envisage the use of electric rotary motors for propulsion; 65% use rubber tyres, wheels and rolls for support and guidance [38] . The putting into operation of air or magnetic cushion supported vehicles cannot be expected in the near future. The electronic equipment needed for height and lateral control, and the energy requirements for support and guidance exceed by far those of adhesive support and guidance techniques. The same applies to cabins frictionally guided by means of feeler wheels; they require much more electronic equipment than positively guided or manually steered (frictionally guided) vehicles.

The development of the linear motor is not yet completed. Its lower efficiency (= higher energy consumption) is matched by some advantages (cf. 3.4.1.). Systems with pneumatic or hydraulic drive and propulsion have not reached any noteworthy importance. Passive vehicles (without drive elements) as proposed for pneumatic or hydraulic propulsion are also envisaged for other concepts (e.g. POMA SYSTEM /F, or cable car in San Francisco). Their disadvantages, i.e. high costs for drive and propulsion elements along the track are partly offset by their advantages, i.e. low costs for vehicles, especially if a large number of small vehicles is operated.

Development in the field of conventional systems is characterized by component improvements (vehicle, guideway operation). A key element in the field of further development is the drive system. Great efforts are devoted towards cleaner and quieter drive systems but in particular to the problem of energy recovery through braking. High personnel costs of transport systems is another concern which encourages new system developments nearly all of which are directed at automated operation. But also for conventional systems, the possibility of personnel reduction constitutes an important impetus for further developments. A higher degree of automation, faster vehicle turn-round speeds, and passenger self-handling are the consequences of such efforts which then give rise to increased maintenance and servicing requirements, need for more technical equipment and surveillance, in order to cope with the resulting increase in criminality and vandalism.

4.4 Conclusions Concerning Individual Systems and System Groups

4.4.1 Taxi

There are no noteworthy improvements, neither technically nor operationally, as far as taxis are concerned. Experiments with steam operated vehicles, as were for instance conducted in the USA, are not specifically limited to taxis but to private cars in general. Operationally it could be of advantage to let taxis use the separate bus lanes, where available. Given the high personnel intensity of the system, efforts should be made to improve turn-round speeds during peak-hour traffic and load factors. Taxis operating along bus routes during off-peak hours on behalf of a public transport operator could improve the productivity of taxi operation and bring about cost savings for bus operators. At present, taxi drivers spend 40% of their duty time on empty runs or waiting [9] [39].

Disadvantages of taxi traffic:

- high surface and energy requirement per journey (like private transport)
- high personnel requirement (one driver per average load factor of 1.3 to 1.8 persons per useful run);
- high transport cost (3 times as high as buses or railways per journey, or 5 times as high per passenger-km [39].

The advantages of taxi operation are:

- comfort and attractiveness for user (high degree of availability in terms of time and place; short transit time; low requirement for information),

- capability for transport functions for which conventional systems for collective transportation are less suited (tangential relations, easy use for old and handicapped passengers),
- very little requirement for infrastructure.

Despite these virtues, it may be useful to limit the number of taxis or licences. According to [39] , the number of taxis in towns and cities where no limitations are imposed, is three times as high as in those with restricted licencing. The amount of traffic carried by taxis varies widely: for instance, in Hamburg 1 out of 25 passengers is carried by taxi; in New York 1 out of 9; and in Washington 1 out of 3 (all traffic). In cities with a rapid transit system, taxis hold a smaller share in the transport market.

In order to improve the load factors of taxis and to reduce their empty runs and waiting times, efforts should be made to further develop the possibilities of taxi services along fixed routes. Consideration should also be given to the possibility of permitting joint use of a taxi by persons not known to each other. Traffic volumes could also be increased by indicating in some form the destinations or routes followed by taxis (as practiced in the USA during World War II).

Further attention should be given to the possible impact of taxi fares and transport regulations on the use of taxis and more particularly on the modal split between public transport and taxis.

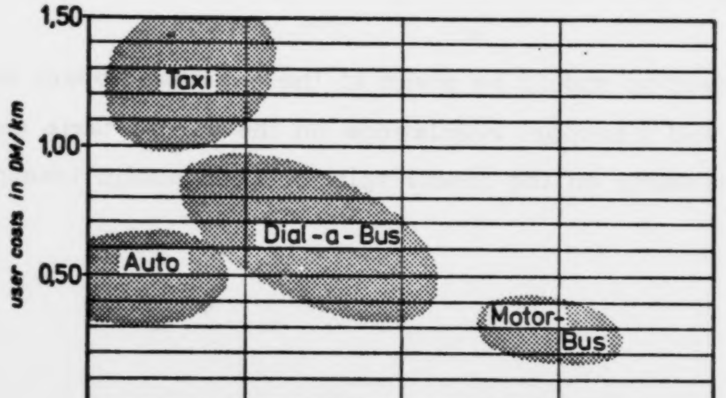
There are various fare systems:

- distance-related fares
- fares varying in the course of the day (higher fares during peak-hour traffic)
- fares per journey or per person carried.

A taxi driver's job in public transport presupposes circumspection and special qualification. In the interest of road safety, governments should lay down regulations to supervise or, where necessary, to restrict the duty hours of taxi drivers (especially if taxi driving is a part time job) and to apply strict criteria for the issue of licences.

4.4.2 Dial-a-Bus Systems

Development and operation of dial-a-bus systems aim at an improvement of the level of service provided. As far as service is concerned, they reach the attractiveness of the taxi, as far as fares are concerned they can be situated between the fare level possible for scheduled public transport on the one hand, and the fare level necessary for taxi operation on the other.



The costs of a dial-a-bus system are closely linked with its operational concept which can vary

- with respect to routing: between absolute flexibility in one service area, or fixed routes in another, with the possibility of deviations from both patterns;
- with respect to dispatch: between an exclusively manual and a computer-assisted dispatch system;
- with respect to telephone communication by the user: between the possibility of using any telephone or the need for special telephones;
- with respect to the pattern of system usage: between a great proportion of ad-hoc trips or a high proportion of regular trips (firm subscriptions).

The degree of cost coverage is determined by the operating concept, but also

- by the density of demand (in turn dependent on frequency of service, population density and size of the service area);
- by the travel time relationship dial-a-bus/private transport;
- by the fare.

Nearly all dial-a-bus systems now in operation are publically funded or receive compensatory payments. In some cases, public assistance is necessary to cover initial costs.

If dial-a-bus systems produce a change in the modal split in favour of public transport, public funds paid towards their operating costs may be a worthwhile economic proposition as they may help to reduce accident rates, reduce or forestall the purchase of second cars and thus reduce the need for further roads and parking space.

The advantages and disadvantages of dial-a-bus systems are comparable to those of taxis:

- high surface and energy requirement per carriage
- high personnel requirement (1 driver for an average of 3 to 8 passengers per useful run);
- higher transport costs than the regular bus service.

but also

- higher riding comfort and attractiveness for the user
- capability for special transport functions
- minimum expenditure for infrastructure.

4.4.3 Bus Systems

Further development of the motor bus operated in scheduled services offers the most promising prospects for improvements. Among the technical developments, it is necessary to mention new drive systems designed to limit pollution (exhaust gases and noises) and to reduce primary energy consumption (dependent on energy source with limited availability) as especially significant. A continuation of these efforts would be as desirable as developments in other technical fields, such as

- vehicle (low vehicle floor, encapsulation of the engine for noise reduction, automatic gears, better seat design and arrangement),
- guideway (longitudinal and transverse slope, evenness, radii),
- stops/stations (protection against atmospheric conditions, information and communication facilities for users).

Also in the field of operation, there is still scope for further improvements for the benefit of users, operators and the general public. The most important measures are:

- installation of separate bus lanes
- priority for buses at traffic lights
- capability for continuous operations control and monitoring.

Facilities for radio communication between buses and the control centre provide the possibility of extending it into an automatic vehicle monitoring system (AVM). American studies have suggested [40] the inclusion of taxis and police cars in the automatic vehicle monitoring (AVM) system, a proposal which can be supported from the point of view of costs and system effectiveness. Wherever possible, the AVM system should be designed to give passengers information at the stations (e.g. about the position of their bus at a given point of time).

All measures directed at an improvement of bus transport increase operators' costs. Nevertheless, these measures are justified considering that in the present situation the bus provides its services in the lower and medium demand range (about 500 to 10.000 passengers/per line, per day in each direction), and at the lowest expenses assumed for costing purposes. The low costs are mainly attributable to the small requirement for fixed installations. When developing improvements for bus transport - involving higher investments - care should be taken not to give up one great asset of the bus, i.e. its flexibility.

Compared with rapid transit railways (capability for coupling of vehicle units) the transport output of a bus driver engaged in scheduled services is low if expressed in seat-km or passenger-km. For the operator, personnel costs are a very important cost factor encouraging measures to reduce personnel costs. They are:

- optimization of vehicle turn-round, time-tables and duty rosters;
- use of large-capacity vehicles (articulated buses and 1 1/2 deckers);
- increase of vehicle turn-round speed (easing of driver's burden with respect to passenger handling duties; special bus lanes; bus priority in traffic;
- operation of scheduled taxi services during off-peak hours (cf. 4.4.1),
- levelling down of bus traffic peaks by staggering working and school hours or by operating special factory-owned buses with factory employed drivers for commuter traffic;
- shifting the main area of operation from public roads to a separate right-of-way providing for automatic (driverless) operation and coupling of vehicles.

This last measure indicates the direction which led to the development of dual-mode systems.

4.4.4 Dual-Mode Vehicles

Technically, dual-mode systems can be realised and put into operation within a relatively short period of time. To put into operation, the dual-mode technique only requires coordination of track-mounted and vehicle-mounted components;

equipment of all vehicles for the use of a separate guideway; and for a start, a relatively small proportion of separate guideway in the total network is needed.

Guidance on a separate right-of-way can be combined with non-polluting battery operation. The battery is charged while the vehicles run on the separate guideway, thus providing for low pollution and low noise operation on public roads while at the same time maintaining the same degree of flexibility as the bus fitted with a combustion engine. The disadvantages of hybrid drive systems are however: heavy weight of the drive system, high energy costs, and the requirement for sufficiently long sections of separate guideway in order to allow for battery charging.

Advantages of the dual-mode system:

- if necessary, and for traffic purposes, only a small proportion of the total network need be designed as separate right-of-way (reduction of infrastructure costs compared with rapid transit systems or cabin systems);
- no need for transfers, unlike split traffic (rapid transit system/bus).
- guideway width can be reduced,
- while on separate guideway, vehicles can be coupled together to form larger units, without great difficulties (thus increasing line capacity),
- operation can be gradually and steadily developed from manual driving and control to automatic headway control, operation and passenger handling;

- personnel savings are possible due to higher transit and turn-round speeds, to coupling of vehicles and possibly also to automatic operation on the separate right-of-way.

Compared with buses, the disadvantages of dual-mode systems lie in the higher capital investments necessary for the separate right-of-way and the vehicles.

Elevated guideways which could be established at lower costs cause other problems, such as problems of space and aesthetic impact, especially when considering that the separate right-of-way is particularly necessary in the inner city areas, more than anywhere else.

Some of the advantages of dual mode-systems (higher transit and turn-round speeds) can also be achieved by the normal bus through provision of separate bus lanes.

Dual-mode vehicles with a small carrying capacity, though improving the level of service on the routes shared with private transport (due to shorter vehicle headways and better area coverage), may considerably increase personnel requirements, unless the percentage of separate right-of-way in the total network is fairly high (personnel savings based on the coupling of vehicles or an automatic operation).

4.4.5 Track-guided Small Cabin Systems

The dominating characteristic of track-guided small-cabin systems is that vehicle capacity is very low (2 to 6 passengers per cabin). In order to achieve sufficient handling capacity, the following steps have been tried:

- coupling of vehicles (the ARAMIS system permits non-mechanical coupling of vehicles during operation);
- travel with relative braking clearance (envisaged for the cabin taxi system, but not pursued further);
- operation with high acceleration and deceleration values (the CVS system is known to have achieved extreme emergency braking decelerations of 19.5 m/s^2 in trial).

Small cabin systems should be designed for a high handling capacity in the interest of reducing costs per passenger-km - in particular with respect to capital service for fixed assets. Handling capacity of public transport systems should be high in order to score an advantage over private transport which can cover much wider areas. Given equal vehicle capacity, handling capacity of private transport is much higher, owing to higher acceleration and decelaration values and the driver's willingness to take risks by reducing relative braking distances; the situation may be different where intersections and junctions are not grade-separated.

Systems operating with individual small cabins can reach line capacities of between 2.500 and 9.000 passenger/h, per track in each direction (see 1st paragraph on this page) without taking into account empty runs of cabins and the gaps necessary at stops to permit cabins to re-enter the stream of traffic. Capacity can be increased through vehicle coupling.

Small cabin systems have a particular traffic problem at stops/stations. Whenever high traffic demands arise inter-

mittently, channelling of passengers to several handling facilities and platforms becomes a problem.
Traffic problems at stops/stations may be of the following nature:

- departure from the off-line track, whenever there are no sufficient gaps on the through track for vehicles to re-enter the line of traffic;
- departure of a cabin from a dispatch position further down the line if preceding cabins impede departure for a specific reason or because of difficulties in connection with passenger boarding or dispatch;
- moving up of cabins while boarding and alighting is still going on;
- diverting vehicles from the through track, if move-up block along the platform is still full;
- limited possibilities to prevent criminality and vandalism.

For financial reasons, small cabin systems will be built mainly with an elevated guideway; their space and surface requirements as well as their functional and aesthetic aspects must be viewed critically, especially when taking into account the space and surface needed for off-line stations.

In addition to high track costs, small cabin systems require a large number of vehicles, the majority of which will only be needed for a short period of time, during rush-hour.
Further considerable cost elements are the highly sophisticated control system and network control computers.

Monitoring, maintenance and servicing of mobile and fixed installations require the highest proportion of personnel, of all public transport systems, if related to passenger-kms.

Furthermore, the following aspects need special consideration and examination

- operational performance in abnormal traffic conditions or in case of failures
- the safety and emergency rescue concept (also for conventional types of escape routes, e. g. protection against improper use);
- protection of guideway against atmospheric conditions in the interest of even adhesion (except for levitated systems), where necessary, heating of guideway (for rubber-tyred vehicles),
- low noise development, especially if a large proportion of the guideway is at surface level or elevated;
- passive switch systems to avoid time losses through reversing;
- measures against criminality and vandalism;
- measures ensuring reliability and safety (escape routes); low incidence of faults through protection of vehicles and guideway against outside interference;
- overload protection, fire protection, communication facilities for passengers in stations and vehicles.

The advantages of small cabin systems must be seen in their attractiveness for the passengers; they might produce a shift in the modal split in favour of public transport. Attractive features are for instance: short transit times, direct routing without intermediate stops (no transfers), availability at any time (with the exception of possible bottlenecks during peak-hour traffic), privacy during the journey and seat availability.

Direct routing may also constitute an advantage which could make small cabin systems attractive for goods transport. Consideration should be given, wherever possible, to the provision of cargo cabins.

4.4.6 Track-Guided Large Cabin Systems

In view of the carrying capacities of these vehicles (between 6 and 50 passengers), demand operation and direct routing are possible only in exceptional cases or for very limited networks. Normally, large cabins will be operated for scheduled services with a fixed time-table and fixed or optional stops for boarding and alighting. Short-term changes in daily demand can be responded to by vehicle coupling, permitting to maintain constant or nearly constant vehicle headways.

The relatively low capacity of the individual vehicle and automatic operation without train personnel permit the maintenance of a high frequency of service, even during off-peak hours. This accounts for a considerable advantage of this system group for its users: short waiting times.

Their capability for coupling permits capacities which can handle nearly any volume of demand, even including

- standing passengers (necessitating lower braking and acceleration values than for vehicles carrying only seated passengers);

- longer vehicle headways imposed by stops (on-line operation).

Owing to their handling capacity, large cabin systems can dispense with off-line stations, which means, compared with small cabin systems

- lower costs for construction and maintenance of infrastructure,
- less equipment for control and operation,
- better physical integration of fixed installations into the urban pattern (except tunnels).

In all applications where there are plans to switch from tramways to an underground-tramway (with the possible intention of subsequently changing to a rapid transit railway), consideration should be given to large cabin systems in view of their capacities - ranging from small cabin systems to large capacity systems - and higher attractiveness. The smaller cross-sections of the cabins also contribute towards reducing building costs for tunnels. Tunnel construction costs can be reduced proportionally to tunnel cross-section.

First hand operational experience is available for automated large-cabin systems. It may be expected that the satisfactory experience made in connection with shuttle and loop services can be adapted to larger networks.

Existing large-cabin systems are currently being used in special limited types of applications (zoos) or by a special category of users (airports). Thus the unavailability of general experience with these systems makes it difficult to predict their susceptibility to criminality and vandalism in a more general type of application, such as public services in a city. Use of these systems will not require a higher degree of passenger involvement than existing rapid transit systems with a small proportion of traffic personnel.

The aspects pointed out in connection with small cabin systems (cf. p. 291) are also important for large cabin systems, over and above the requirement for an adequate volume of demand in order to keep costs per passenger-km down.

4.4.7 Track-Guided Large-Capacity Systems

For automatic systems with vehicles holding more than 50 passengers, the same applies as under 4.4.6. However, track-guided systems with large-capacity vehicles operated with crew personnel have to be assessed differently. The range of functions of the crew personnel may include

- surveillance of passenger boarding and alighting,
- ticket sale, ticket control, ticket cancellation;
- vehicle dispatch (closing of doors)
- vehicle starting
- acceleration (e.g. up to power disconnection point)
- track observation
- response to signal and switch positions, building works, narrow bends, and other events (braking).
- braking and "accurate" stopping in the station.
- communication with the control center
- information of passengers.

Depending on a system's level of automation, the above functions can be reduced to track observation and response (capability for intervention into automatic operation). Automation need not necessarily involve personnel savings but can

- increase transport and turn-round speeds by automating dispatch and traffic functions;
- improve acceleration and deceleration performances by abandoning manual braking and transmission functions,
- save energy through optimum trip cycles and accurate braking,
- avoid break-downs caused by human failure.

The potential for automation for systems operating on public roads, such as tramways is very limited. In terms of track costs, they are more favourable than systems with a separate right-of-way. This implies further advantages such as flexibility of the infrastructure, good physical integration in the urban pattern, in terms of space and surface requirements, but also from the user's point of view, such as good access of stops and information facilities.

Great importance must also be attributed to the disadvantages of these systems, such as low transport speed, a low level of comfort, irregularities of service, insufficient weather protection, high susceptibility to failure and high personnel costs (for driving and maintenance). Operating and traffic performance of the crew personnel are affected by reduced system capacity caused by

- interference from private transport
- traffic signals
- maximum speeds on public roads
- limitation of maximum vehicle lengths (about 80 m) and widths (2.65 m [FRG], 2.75 m [US] - in each case for tramways)

In the city centres, tramway or rapid transit railway transport is made far more attractive by the provision of a separate right-of-way or failing that an exclusive track with coordinated traffic signals. Also outside the city centres 20 to 50% of the network should be operated on an exclusive right-of-way.

For existing, tramways and rapid transit which currently share the right-of-way with private transport, it may be possible to shift gradually to an exclusive right-of-way approach thus enhancing the attractiveness of these systems in an evolutionary manner. The end result of such an approach could be a largely or fully automated rapid transit system, operating exclusively on its own right-of-way.

Where it is clear that the demand cannot be raised to support a high level of service with a large capacity system, an automated large cabin system may be the preferable approach because of its ability to sustain higher trip frequencies.

When making judgements about the desirability of building a rapid transit system, the main factor to be considered is costs per passenger-km, mainly determined by the costs of the guideway. Other factors likely to influence the decision in favour of a rapid transit system are: improvements in the general transport infrastructure, savings in road construction, higher land values, especially in inner city areas (real estate prices); contribution towards traffic safety, effects on the urban development pattern and higher attractiveness for users (regularity of service, higher transport speeds).

Joint use of tracks by long and short-distance traffic can only be justified in applications with low traffic demand, to keep track costs per passenger-km at a reasonable level.

4.4.8 Continuous Conveyance Systems

Continuous conveyance systems have not previously been considered in the framework of this study, since they serve distances which could also be covered on foot, e.g. if the system breaks down. Consequently, they can be characterized chiefly as pedestrian aids and are primarily designed to enhance the attractiveness of other transport systems. However, in addition to this complementary function, they can also operate as a service in its own right in wider activity centres, over distances up to 5000 m. Apart from conventional moving pavements and escalators, paternoster lifts and elevators, this group also includes express pavements operating at speeds of > 1 m/s and over distances of > 300 m, as well as continuously moving cabin systems, so: technically very different systems.

Advantages of continuous conveyance systems are:

- automatic operation (no traffic personnel, except for surveillance)
- possibility of immediate use (no waiting times)

- mostly free-of-charge transportation (no need to study fares and fare regulations)
- little or no expense for transport unit,
- high capacity in relation to surface and space requirement.

Conventional moving pavements and escalators, those are e.g. continuous systems with a band or step width of 1.2 m and travel speeds of 0.7 m/s, can reach a practical carrying capacity of 9000 persons per hour in each direction [41]. At higher travel speeds, carrying capacity decreases, due to the psychological effect on passengers of higher speeds, i.e. reluctance or fear to step onto or off the continuous conveyor.

To avoid queues building up, transport speed must not be higher than stepping off speeds of users.

The above statement does not, however, apply to express pavements linked with accelerator systems (before, behind or parallel). Some system developments like Speedway, or the Transurban Conveyor, are reported to operate transport speeds up to 25 km/h and to handle a high volume of traffic at constant speed.

Continuous conveyance systems can also be used to overcome height differences. In the interest of convenience, angles of inclination should not exceed 12°. Where the angle of inclination is more than 8°, easement curves should be provided at the bottom and top, for convenience and greater safety.

The disadvantages of continuous conveyance systems are:

- limited operational flexibility; no possibility to vary conveyor speed or carrying capacity;
- relatively high accident risk (about 20% to 30% of all accidents recorded in installations of rapid transit systems occur on or at the escalators, although all exits and accesses are not equipped with escalators and only a certain proportion of passengers use them);
- relatively high energy costs in relation to passenger-kms;
- high susceptibility to failure (according to [14], the serviceability of escalators is below 90%);
- in the event of break-down or maintenance and servicing, the whole system has to be stopped;
- low area coverage as, in general, only point-to-point services are provided; pedestrian traffic is obstructed by at least one railing;
- stepping off sideways from the conveyor belt (in transverse direction of travel) would increase the accident risk and impede or prevent use by certain categories of passengers;
- limited capability for extension; extension and shortening involve reconstruction of the entire system and its temporary discontinuation;
- some technologies are not suited for curves (rubber belts) or gradients (articulated conveyor belts).
- on moving pavements with acceleration and deceleration segments congestions may occur when passengers leave the moving pavement at the deceleration segment

In conslusion it can be said that although continous conveyors are desirable pedestrian aids, their installations should be carefully considered in each individual case, in the light of the above advantages and disadvantages.

Continuous conveyance systems as short-distance transport systems in their own right will be limited to few clearly defined applications, such as point-to-point transport relations, serving an even volume of demand.

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ANNEX 1

ANNEX 2

ANNEX 3

Questionnaire for Short-Distance Transport Systems of Group:

Name of System:

Name and address of manufacturer or designer:

Area of application/test facility:

State of development:

Technical Data

I. Vehicles

a) Vehicle description:

b) Dimensions: length ... m; width ... m; height ... m;

c) Boarding and alighting:
Difference between vehicle floor and platform ... mm;

d) Vehicle weight: empty ... kg; loaded ... kg;

e) Materials:
Vehicle body:
Chassis:

f) Passenger accommodation:

Seated passengers:

Standing passengers (based on 0.25 m^2/standing passenger):

g) Air conditioning:

Heating:

Ventilation:

h) Support and guidance technique:

Method of switching:

i) Propulsion:

k) Performance data: v_{max} = km/h = m/s

Maximum take-off acceleration:	m/s^2
Mean take-off acceleration up to 14 m/s:	m/s^2
Mean operational braking deceleration:	m/s^2
Emergency braking deceleration:	m/s^2
Maximum climbing ability at ... m/s	%
Maximum climbing ability at reduced speed	%

II. Fixed Installations

---

a) Right-of-Way:

b) Guideway construction:

Track gauge:

Width of standard clearance for both directions of travel with and without room for emergency escapeway (0.7 m): m

Minimum radius of curvature ... m

Diameter of turning circle ... m

c) Track dimensions:

d) Method of switching:

e) Stops/stations:

Length of platform: m

Width of stop/station: m

Length of stop/station: m

Average distance between stops/stations: m

f) Control and safety system:

g) Power supply:

III. Operation

a) Mode of operation:

b) Nature and frequency of service:

c) Type and number of coupled vehicles:

d) Maximum train capacity (at 0.25 m^2 per standing passenger): .... passengers

e) Carrying capacity (at 0.25 m^2 per standee):

Max. theoretical capacity ... passengers/h in each direction at a vehicle frequency of ... seconds.

Max. practical capacity about ... passengers/h in each direction.

Costs/Capital Requirements

a) Capital investment - fixed plant: DM/km double track

capital investment for underground / surface-level / elevated guideway:

capital investment - stops/stations: DM/stop or station

b) Capital investment - vehicle: DM/vehicle

V. a) Pictures and Diagrams of Vehicles

V. b) Pictures and Diagrams of Right-of-Way (Switching)/ Stations

Explanatory Notes on the Completion of the Questionnaires on Short-Distance Transport Systems

Name of system:

Indicate the most common name of the described system (acronyms or abbreviations should be explained).

Name and address of manufacturer and designer:

Indicate name and address (town and country) of the firms with main responsibility for the development and construction of the system. The role of each compnay should be indicated.

Area of application/test facility:

In respect of test facilities for new-type systems indicate nature of facility, date and place of their putting into operation; the area of application can be one specific place or a number of different places (without specification).

State of development:

by the date of submission

Give information about vehicle, guideway and operation; for conventional systems it will suffice to state "in operation".

I. Vehicles

a) Vehicle description:

Follow the classification:

supported vehicles, suspended vehicles,

use general designations such as:

single or articulated motor cars

two-unit motor cars close-coupled (married pairs) or three-unit motor cars close-coupled;
single-ended or double-ended operation, with/or without trailer.
(Attached to the explanatory notes is a list of conventional rail mounted vehicles)

b) Dimensions:
length data include couplings, bumpers, etc.
width is exclusive of door handles, rear view mirrors etc.
height data are measured:
- for vehicles running on the guideway: from the upper edge of the rail or the guideway surface:
- for vehicles with overhead power-pickup: to the upper edge of the power trolley in lowest position;
- for suspended vehicles: from the lower edge of the guideway.

c) Boarding and alighting:
Indicate boarding and alighting arrangements:
(on one side, on both sides, at the front or rear)

and functioning of doors:
(sliding, swing-out/sliding, folding, turning swing-in or swing-out doors)

In addition to indicating the number of single and double doors specify widths (clear width), and heights and, where applicable, list separately doors for passengers, operating personnel and emergency exits.

For the height difference between vehicle floor and platform, indicate the extreme values including design tolerances (e.g. for empty vehicle).

d) Vehicle weight:

The data for empty and laden vehicle should correspond with the design data for empty weight and maximum permissible total weight, drawn from works manuals; they should not be calculated on the basis of 0.25 m^2/standee and 65 kg/person.

e) Materials:

Only consider vehicle carcass;
break down, where applicable, into materials for cabin, chassis, wheels etc; interior design and equipment can be ignored, as they are not system specific.

f) Passenger accommodation:

Flap seats or tip-up seats are mentioned separately; in the interest of data uniformity, specify number of standing places on the basis of 0.25 m^2/standee; seat arrangements should be described in detail and, wherever possible, add pictures.

g) Air conditioning:

Indicate type and capacity of the air conditioning systems used, size of equipment, capital costs, power consumption etc.; specify also control method, energy source (for heating); type of ventilation (natural: through windows or skylights or artificial: by means of a fan).

h) Support and Guidance Technique:

Describe the support and guidance components for straight-on movement and switch-passing; such elements are: steel and rubber wheels, levitation techniques (pneumatic and magnetic), suction; to describe guidance system give additional information about adhesive friction, wheel flange, restoring force of the LIM etc.; for levitated systems or pneumatically supported systems describe, where applicable, methods of emergency support (e.g. supplementary steel wheels, special emergency undercarriages or sleds).

i) Propulsion

Type and conversion of energy, e.g. electric power (external conversion of primary energy); specify types and numbers of energy converters per vehicle and performance (unless otherwise specified: maximum one-hour rating in kW). Add information about control and steering systems (manual control, automatic control, camshaft gear, contactor control and thyristor control).

k) Performance data:

Indicate values for maximum speed and maximum acceleration at take-off, which is usually in the lower speed ranges and give an indication of the standard of passenger comfort provided by the system. For comparison of traveling speeds it would be useful to have also the values for mean take-off acceleration from O to the maximum operating speed (e.g. for buses about 50 km/h).

The value given for operational deceleration under the influence of braking should be a mean value of deceleration from the maximum operating speed; as a comparative value for passenger comfort and the degree of safety provided by the vehicle (mainly interesting for standees) information is requested about the maximum emergency deceleration capability (empty vehicle, dry carriageway); the mean values for acceleration and deceleration shall be based on 50 % vehicle occupancy and good carriageway conditions; maximum hill-climbing ability shall be related to maximum speed, or, if speed reduction allows steeper gradients, indicate maximum performance and limitations due to weather conditions (static friction under conditions of ice and snow).

II. Fixed Installations:

a) Right-of-Way

The nature of the right-of-way can only be described for conventional systems. Indicate which proportions of the track are:

- elevated, in embankment, cutting or tunnel,
- on a separate right-of-way in open country,
- as a separate track within the traffic space of public roads and/or separated from motor traffic by road markings,
- sharing with motor traffic.

For most systems, information has to be limited to the following indication: separate right-of-way; sharing fully or partly with private transport.

b) Guideway construction:

Analogously to the data given under I h, describe here the support and guidance elements installed in the guideway; guideway information also includes additional equipment such as noise protection devices, power supply units, communication etc.; gauge data (in mm) for tangent sections.

Indicate overall width of clear space for both directions, add, where applicable, safety clearance; relate min. radius of curvature to operating speed; where smaller radii are possible at lower speeds (for instance in maintenance and service depots) they should be specified separately.

c) Track dimensions:

Describe superstructures and substructures, as for instance for railway lines; for guideway girders from which vehicles are suspended or astride of which they are moving, specify height and width of girder, but also the clear maximum height above the road surface (or height of supports).

d) Method of switching:

Indicate type of switches (active or passive and, where applicable, horizontal or vertical), length of switch and smallest switch radius; information about action of vehicle and guideway when running over a switch is requested only for newer systems.

e) Stops

Depending on whether the platforms are situated along the traffic lane/track or along a side track, a stop is defined as on-line or off-line; the length of the platform is usually determined by the maximum train length plus a safety margin. For single units (not capable of train formation) describe a simple station arrangement; space requirement is an important factor of off-line stops: indicate length of the off-line track (from branching-off point to branching-in point = switch rail of conventional railways). The width of a stop is determined by the width of one platform including one traffic lane/track (two for off-line stops).

f) Control and safety system:

List the different elements and techniques available, i.e. headway control:

- no special safety techniques (visual driving),
- continuous signalling or block systems combined with track monitoring by means of d.c. high frequency circuits or axle counters),
- headway control by means of synchronous propulsion.

Other safety systems:

- dead-man's handle in the vehicle,
- inductive train control by means of vehicle and track magnets,
- radio surveillance and information.

g) Power supply:

For outside power supply by contact line distinguish between overhead power line and contact rail; give data about nature of current (a.c./d.c.), frequency, voltage etc.; information about voltage and frequency control is significant for linear induction motors.

For vehicles equipped with on-board power supply, describe process of power conversion and nature and design of power storage system (e.g. fuel tank with a capacity of ....l).

III. Operation

a) Mode of operation:

The following aspects should be covered by the description of the mode of operation:

- fixed, flexible or no route pattern,
- fixed, variable or no stops,
- call at each stop/station, upon request, or only at a limited number of intermediate stops,
- origin-to-destination travel without intermediate stops.

b) Nature and frequency of service:

Distinguish between scheduled services, at regular or irregular intervals, and demand operation; try to estimate waiting times as a function of frequency and regularity of service as well as other influencing factors.

c) Type and number of coupled vehicles:

Indicate powered cars and trailers; their position and arrangement in the vehicle train; length, number of seats; specify train length for the maximum permissible number of coupled vehicles.

d) Maximum train capacity

Indicate maximum number of seats and standees in the largest train unit.

e) Carrying capacity:

The theoretical carrying capacity is calculated on the basis of the longest possible trains operating at minimum intervals and a 100 % load factor (based on 0.25 m^2/standee); the actual carrying capacity can be estimated on the basis of a reasonable maximum load factor, a realistically estimated vehicle headway including necessary time reserves, and other factors reducing the theoretical capacity; a system with off-line operation must, for instance, provide for a sufficient number of gaps in the main traffic stream in order to allow vehicles on the off-line track ready for departure to merge into the main traffic line.

IV. Costs/Capital Requirements

Wherever possible indicate, in addition to capital costs, information about the life-time of fixed plants and vehicles.

a) Capital investment - fixed plant

As the costs for land purchase, clearing (demolition of buildings and relocation of pipes), compensation of neighboorhood etc. cannot be estimated for new systems, these data will not be required for conventional systems. Total capital requirements comprise the shell costs for traffic lanes in both directions (including supports), costs for stations handling average passenger volumes; off-line stations also include the costs of the side-track; all finishing costs including permanent way, cladding, contact system, safety devices etc.; where costs of shunting tracks, depots and substations are included, please specify separately; as the level of the right-of-way has a considerable impact on capital requirements, specify capital investments for underground, surface-level and elevated guideways separately.

Specify separately the costs for a standard station; for off-line stations indicate the costs of the additional traffic lane in order to permit evaluation of their effect on total capital investment and operating costs, and their effect on the attractiveness of the system; an important factor is distance between stations (cf. II e).

b) Capital investment - vehicle:

The cost of a fully equipped vehicle should be based on a minimum number of vehicles (more than 100 vehicles).

V. Pictures and Diagrams

a) Vehicle

Side, rear and front views; wherever possible, add plan view including seat arrangement.

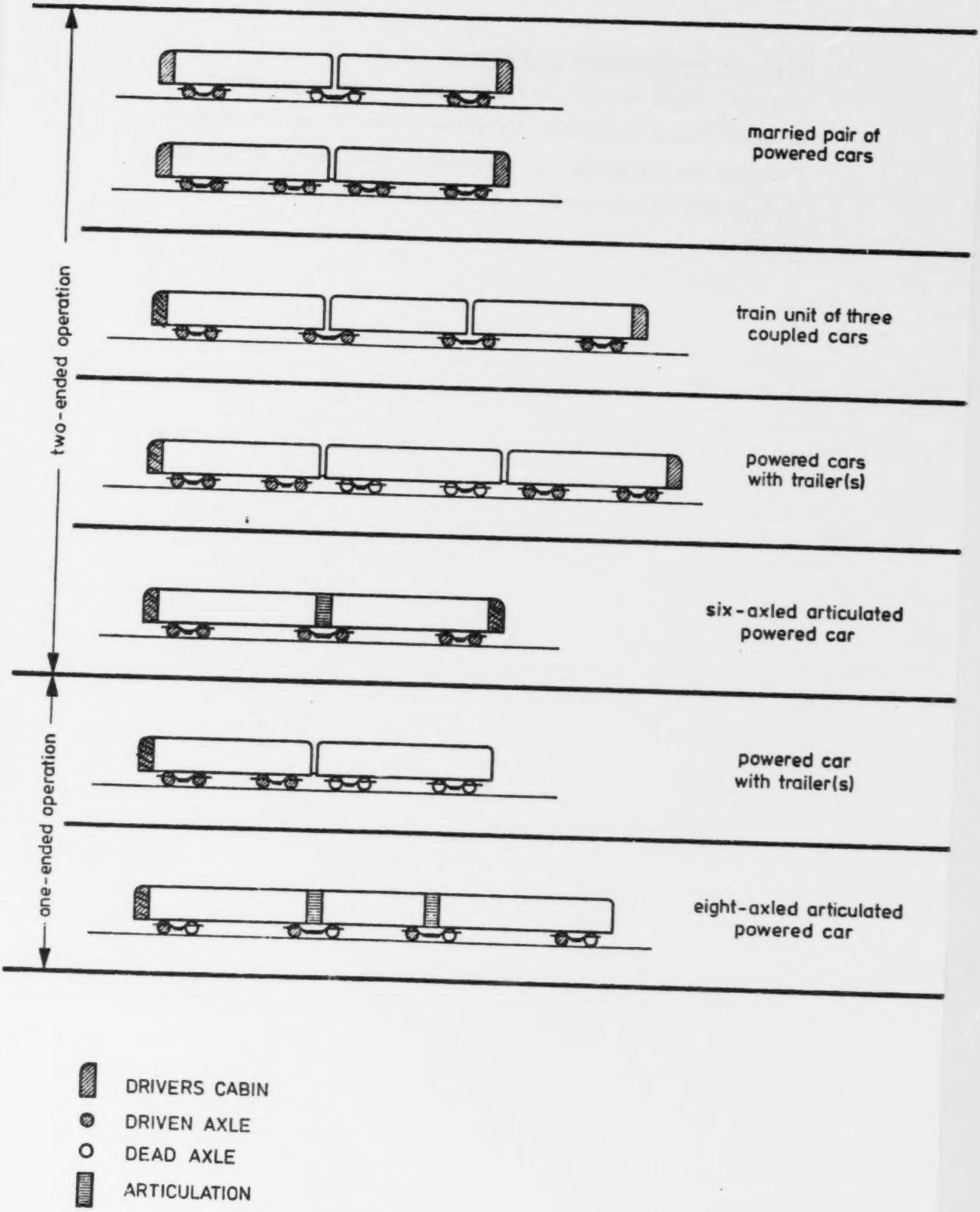
Undercarriage and other details necessary for a better understanding of the system should be shown separately, if possible.

b) Right-of-way (switching)/stations:

Present cross-section of track and, where applicable, of other track elements. Give plan view of switch system. Pictures and drawings of stations in plan view, longitudinal section and cross-section, or in perspective view, are welcome.

Annex 2

ILLUSTRATION OF TRAIN UNITS


two-ended operation
one-ended operation
married pair of powered cars
train unit of three coupled cars
powered cars with trailer(s)
six-axled articulated powered car
powered car with trailer(s)
eight-axled articulated powered car
DRIVERS CABIN
DRIVEN AXLE
DEAD AXLE
ARTICULATION

Questionnaire for Short-Distance Transport Systems of Group: Taxi

Name of System: Taxi
type selected: Mercedes 240 D

Name and Address of Manufacturer or Designer:
various vehicle manufacturers, e.g. Daimler Benz AG
7 Stuttgart 60 (Untertürkheim), FRG

Area of Application:
all cities in the FRG

State of Development by the End of 1974: operational

TECHNICAL DATA

I. Vehicles

---

a) **Vehicle Description**
wheel-supported, self-propelled vehicle

b) **Vehicle Dimensions:**

length	4.86	m
width	1.77	m
height	1.44	m

c) **Boarding and Alighting:**
two swing-out doors on each side, each with a clear width of 0.90 m, and 1.05 m high.
Difference between vehicle floor and ground level is 390 mm.

d) **Vehicle Weight:**

curb weight	1390 kg
gross weight	1910 kg

e) **Materials:**
vehicle body in light steel construction; chassis: steel structure; wheels rubber-tyred.

f) **Passenger Accommodation:** 3 (4) passengers seated
all seats are arranged transversely, in the direction of travel; trunk: 0.53 m^3.

g) **Air Conditioning:**
heating: through engine heat
ventilation: natural ventilation through windows or sliding roof, where available.

h) Support and Guidance Technique:

support and guidance are provided by 4 rubber wheels (diameter 531 mm); guidance is performed through steering and adhesion.

i) Propulsion:

Diesel combustion engine: 65 metric HP = 47.8 kW
gear-shift or automatic transmission.

k) Performance Data:

v_{max} = 130 kmh = 38.4 m/s

maximum take-off acceleration up to 16.7 m/s	:	1.8 m/s^2
mean operational braking deceleration	:	ca. 2 m/s^2
emergency braking deceleration	:	ca. 5 m/s^2
maximum climbing ability at reduced speed	:	10 %

II. Fixed Installations

---

a) Right-of-way:

taxis use the normal city street network sharing it with private transport

b) Guideway Construction

Streets and roads are mainly covered with a bituminous course, rarely with pavement.

gauge:	front wheels:	1450 mm
	rear wheels	1440 mm

standard width of carriageway for both directions excluding safety space: ca. 5 m
turning circle: ca. 11 m

c) Track Dimensions:

track width is identical with standard width of carriageway; height of surface course is about 0.3 m.

d) Method of Switching: ----

e) Stops and Stations:

apart from taxi ranks no fixed stopping places; length of taxi rank is determined by the number of vehicles usually using it.

f) Control and Safety System:

no special safety technique (visual driving); in most cases, driving only with relative braking distances; monitoring and information via radio.

g) Power Supply

on board power supply through combustion; energy store = fuel tank for 65 l Diesel.

III. Operation

---

a) **Mode of Operation:**
no fixed routes and fixed stops; only demand-operated and directly routed.

b) **Nature and Frequency of Service:**
immediate pick-up of passenger if taxi is available at taxi rank, or waiting time until the next taxi arrives; or if taxi is requested over the telephone.

c) **Type and Number of Coupled Vehicles:** no coupling possible

d) **Maximum Capacity** (at 0.25 m^2 per standing passenger) of one vehicle:
3 (4) passengers seated

e) **Carrying Capacity:**
Max. theoretical capacity: 3375 (4500) passengers per hour in each direction at a vehicle headway of 3.2 s = 45 m.
Max. practical capacity: 1050 passengers per hour in each direction due to time losses at traffic signals (assumed time loss of 30%) and an average load factor of 1.33 passengers.

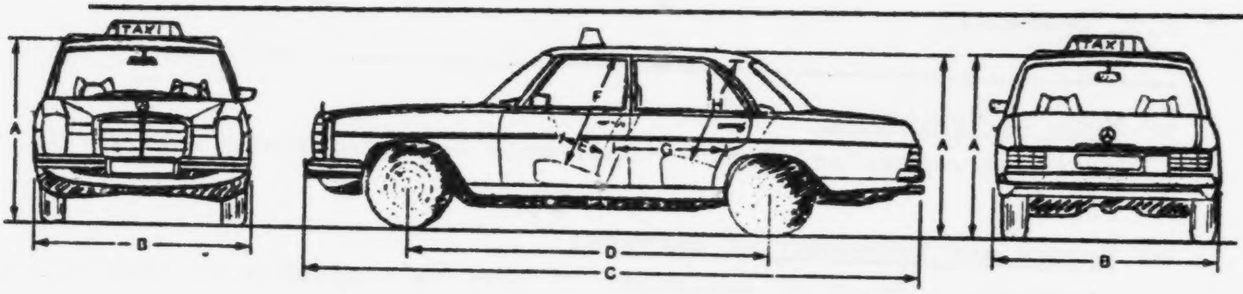
IV. Costs/Capital Requirements

---

a) Capital investment - track : ----- } to be neglected
b) Capital investement - stop/station: ----- } to be neglected
c) Capital investment - vehicle: DM 15.984 (life-time about 4 years)

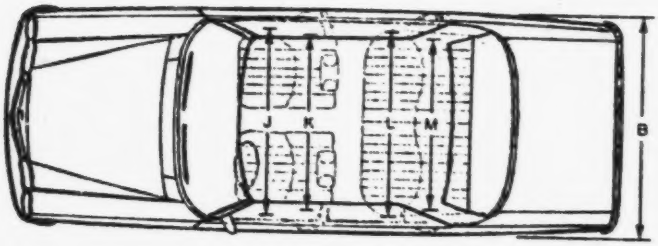
Va) Pictures and Diagrams of Vehicles

Annex 3



Front, rear and side view of the vehicle

A	max height, empty vehicle	1440 mm
B	max. width	1770 mm
C	max. length	4680 mm
D	wheel base	2750 mm
E	steering wheel - driver seat back 5)	400 mm
F	height, front seat to ceiling, empty vehicle	965 mm
G	distance driver seat back to rear seat back 5)	755 mm
H	height, rear seat to ceiling	860 mm
J	interior width, middle of front seats	1490 mm
K	interior width, at the level of front window cranks	1410 mm
L	interior width, middle of rear seats	1485 mm
M	interior width, at the level of rear window cranks	1405 mm



Plan view and seat arrangement

Questionnaire for Short-Distance Transport Systems of the Group: Dial-a-Bus

---

Name of the System: Tele Transpo

Name and Address of Manufacturer or Designer:

System Designer +)

Ottawa-Carleton Regional Transit Commission (OC Transpo),
1500 St. Laurent Boulevard
Ottawa, Ontario,
Canada

Equipment Manufacturers ++)

Twin Coach,
789 Stow Street,
Kent, Ohio, 44240
U.S.A.

Rek Vee Industries Ltd.
Funcraft Vehicles,
Cambridge, Ontario

Wayne Corporation
Windsor Ontario,
Canada, N8Y 4W5

Area of Application

The Tele-Transpo dial-a-bus system has been implemented in the Ottawa region in nine low density (11 persons/acre) fringe suburban areas which appeared to be difficult to serve efficiently with conventional fixed route transit service.

+) Dial-a-bus is an operational rather than hardware innovation and it is difficult to cite any one group as having developed this concept. In this instance the staff of OC Transpo designed the specific application of dial-a-bus described in this example.

++) There are many manufactuers of the type of small bus used in dial-a-bus service. This list includes only those three small bus manufacturers who have supplied equipment to the Tele Transpo system to date and this list is not to be interpreted as an endorsement of these manufacturers.

State of Development by the End of 1974

The Tele-Transpo dial-a-bus system has been fully operational since August 1973. In its present configuration the system uses conventional proven small bus vehicles and manual dispatching techniques. The real innovation in dial-a-bus is not in the hardware, therefore, but in the mode of operation which provides transit service from the user's home on demand.

Consideration is currently being given plans to extend the service during off-peak periods from the present many-to-few mode of operation (i.e. riders are picked up at their homes and delivered to a few central activity centers where they can transfer to the fixed route system) to full scale many-to-many service (riders are picked up at their homes and delivered in taxi fashion to any destination of their choice). Such an expansion of service will require the development and installation of more sophisticated dispatch and communication equipment than are currently in service.

TECHNICAL DATA

I. Vehicles

---

a) Vehicle Description:

OC Transpo currently operates three types of small buses in its Tele-Transpo service. These are:

- Twin Coach (Diesel)
- Wayne Wells (Gasoline)
- Rek Vee (Gasoline)

A new diesel version of the Rek Vee vehicle is currently being evaluated by OC Transpo and it is the specifications of this vehicle that are provided below as an example of the typical small bus used in dial-a-bus service. The selection of this particular vehicle is purely arbitrary as any other manufacturer's vehicle would serve equally well. The fact that this particular specification has been selected is not to be interpreted, therefore, as an endorsement of this particular model or manufacturer.

b) Dimensions

Length including Bumpers	7.3460 m
Width	2.4384 m
Height, Exterior	2.8048 m
Height, Floor	0.7620 m
Height, Ground to Step	0.3429 m
Headroom	1.9050 m
Wheelbase	4.0386 m
Width, Interior (Maximum)	2.2352 m
Turning Radius	9.1440 m

c) Boarding and Alighting

Door:

The single entrance/exit door is an electrically operated sedan type (swing out) which is circuit breaker controlled.

Step:

The stepwell area is moulded fiber glass covered with R.C.A. rubber step treads. The step height from the ground is 0.36 m with two 0.22 m step risers.

d) Vehicle Weight

Curb Weight +	4,218 kg
Gross Vehicle Weight ++ 17-Passenger Club Car	5,445 kg
Gross Vehicle Weight ++ 24-Passenger Transit Seating	5,923 kg

e) Materials

Body Structure

The body is manufactured as a single unit using rigid foam as the core material sandwiched between two skins of reinforced fiber glass with an overall thickness of 1 1/2 ".

+ With fuel, coolant, oil. No driver or passengers.

++ Curb weight plus driver and passengers at 68.2 kg.

The exterior surface of the body is coated with gelcoat to form a hard, scratch-resistant surface which is easily cleaned. Extra layers of glass laminate are applied where strength is required. The area around the entrance door is multi-sandwich construction for added strength.

Body Interior

The roof is moulded fiber glass. Side panels are made from 3/16 inch plywood.

f) Passenger Accommodation

24 passengers seated

g) Air Conditioning

No air conditioning provided.

h) Support and Guidance Technique

Suspension

Front leaf springs are rated at 2,300/2,525 at ground pad; rear leaf springs at 3,400/3,800 at ground pad. Heavy-duty shock absorbers and sway bar are provided front and rear.

Tire Sizes

Goodyear tubeless 8.00 x 19.5 " front and back are supplied.

Wheels

Wheels are single front and dual rear and interchangeable. They are BUDD type, stamped steel, ventilated RIM, 19.5 x 6 inches, 5-stud.

Steering

A Saginaw powered steering mechanism with recirculating ball is provided. Steering from full right turn to left turn can be accomplished in no more than six complete turns of the steering wheel. The steering mechanism is self-centering.

i) **Propulsion**

Deutz Diesel air cooled 6FL912W

Double Combustion	
Compression ratio	17:1
Net horsepower	113 hp at 2000 rpm
Net torque	213.4 lb.ft at 1550 rpm
Bore and stroke	3.93 x 4.718 in.
Piston displacement	344.9 cu.in.

k) **Performance Data**

Operating Range

This bus operates at a minimum range of 250 miles over a typical city bus cycle.

Performance at GMWR

Maximum road speed is 70 mph. The vehicle is capable of maintaining 70 mph on a 3% grade and 60 mph on a 6% grade.

mph	Engine Speed rpm	Net Grade Ability %	Acceleration Rate mph/s
30	1436.4	19.45	3.98
40	2394	9.11	1.822
60	2872	5.82	1.164
70	3351	3.003	0.6006

II. Fixed Installations +)

a) **Track:** Dial-a-bus systems use the normal city street network.

b) **Stops and stations:**

The dial-a-bus system has no fixed stops other than the point of rendezvous with the fixed route system. Users of the system are picked up at their homes.

c) **Control and Safety Systems**

Control of the vehicle fleet is exercised through the dispatch centers located in each of the service areas. All vehicles are

---

+) Questions b) through d) of the questionnaire dealing with track dimensions, guideway construction and the method of switching do not apply to dial-a-bus systems and are, therefore, deleted.

radio equipped permitting communication with the control center in the event of a vehicle breakdown or other emergency.

d) Power Supply

On board diesel engine.

III. Operation

a) Mode of Operation

As previously mentioned, dial-a-bus is an operational rather than a hardware innovation and hence the question of the mode of operation is really the heart of the matter.

Frequency of Service

In each of the nine service areas Tele-Transpo operates a small bus which circulates through the area on a fixed time cycle (every 30 minutes). This compares favourably with the equivalent fixed route schedules in suburban areas which generally also average 30 minutes headways.

Bus Routing

Each Tele-Transpo duty cycle begins at a major activity center (normally a shopping center) where the Tele-Transpo interfaces with the fixed route transit system. From this base the buses then follow variable routes through the service area in response to the demands received for service.

Requests for Service

Users are required to telephone the local Tele-Transpo control center to obtain service. These calls must be placed at least 30 minutes prior to the time the system user wishes to be picked up at his(her) home. Users must supply the receptionist with their trip destination, home address, phone number and desired time of departure. Users may reserve trips in advance any time between 6.30 a.m. and 11 p.m. seven days a week.

Dispatch Function

The information on each demand for service collected by the receptionist is passed to a system dispatcher who uses this data to prepare vehicle run sheets for each vehicle cycle. These run sheets list the addresses of all those users wishing service during that cycle. The run sheet is then passed to the bus driver at the beginning of each run and the driver himself determines the order in which the users will be picked up at their homes and the route the bus will follow to make these pick-ups.

Return Trips and Trips Outside the Service Area

The dial-a-bus of the Tele-Transpo system acts as a feeder to the fixed route bus system. The Tele-Bus vehicles rendezvous at the end of each duty cycle at the activity center with a regularly scheduled fixed route bus. Tele-Transpo users can then transfer to the city-wide fixed route system free of charge to continue their trip to anywhere in the OC Transpo service area.

For return trips, users simply board the bus at the control center, ensuring that the vehicle they board displays the appropriate zone number of their destination, and inform the driver of their destination.

b) Nature and Frequency of Service

The Tele-Transpo vehicles circulate through the service areas every 30 minutes and the passenger waiting time (re: time difference between the time the service is requested and the actual time of pick-up) is less than five minutes on the average.

c) System Capacity +)

The theoretical capacity of the Tele-Transpo system is 100 person trips per hour per vehicle. The practical capacity, however, is approximately 30 persons per hour, because of system inefficiencies

---

+) Questions c) through d) of the questionnaire dealing with the type and number of coupled vehicles, the carrying capacity of the largest train unit and the carrying capacity at $0.25m^2$/standee do not apply to dial-a-bus operations and are, therefore, deleted.

introduced by people not being ready when the vehicle arrives at their home, suburban street systems which do not permit efficient routing of the bus, and the dispersed nature of the demand.

IV. Costs/Capital Requirements +

---

a) Capital Investment - Equipment:

Twin Coach	$ 28,000	
Rek Vee	21,000	($ 32,000 for diesel)
Wayne Wells	16,000	

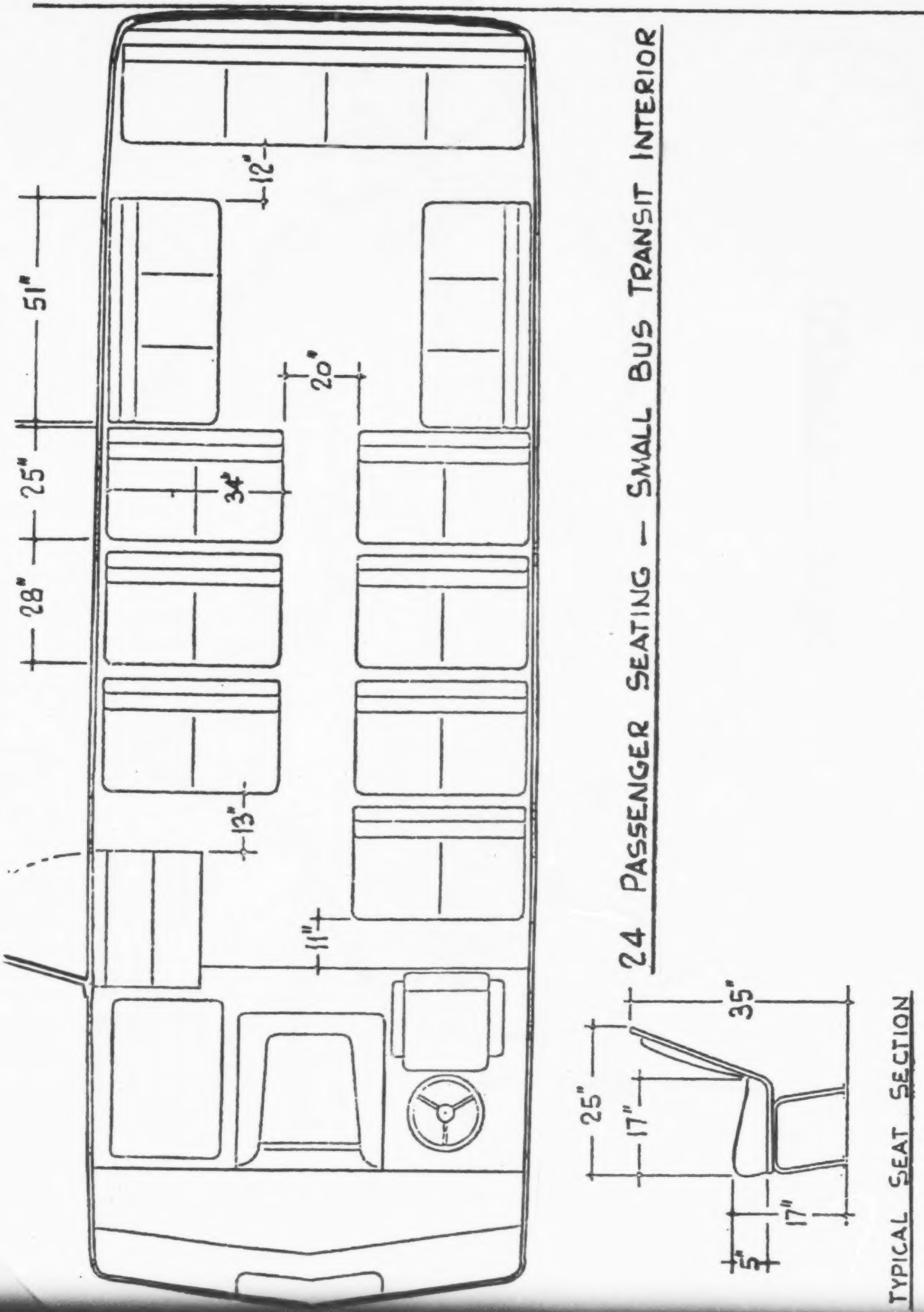
b) Operating Costs

Cost/bus mile	$ 0.84
Cost/bus hour	9.93

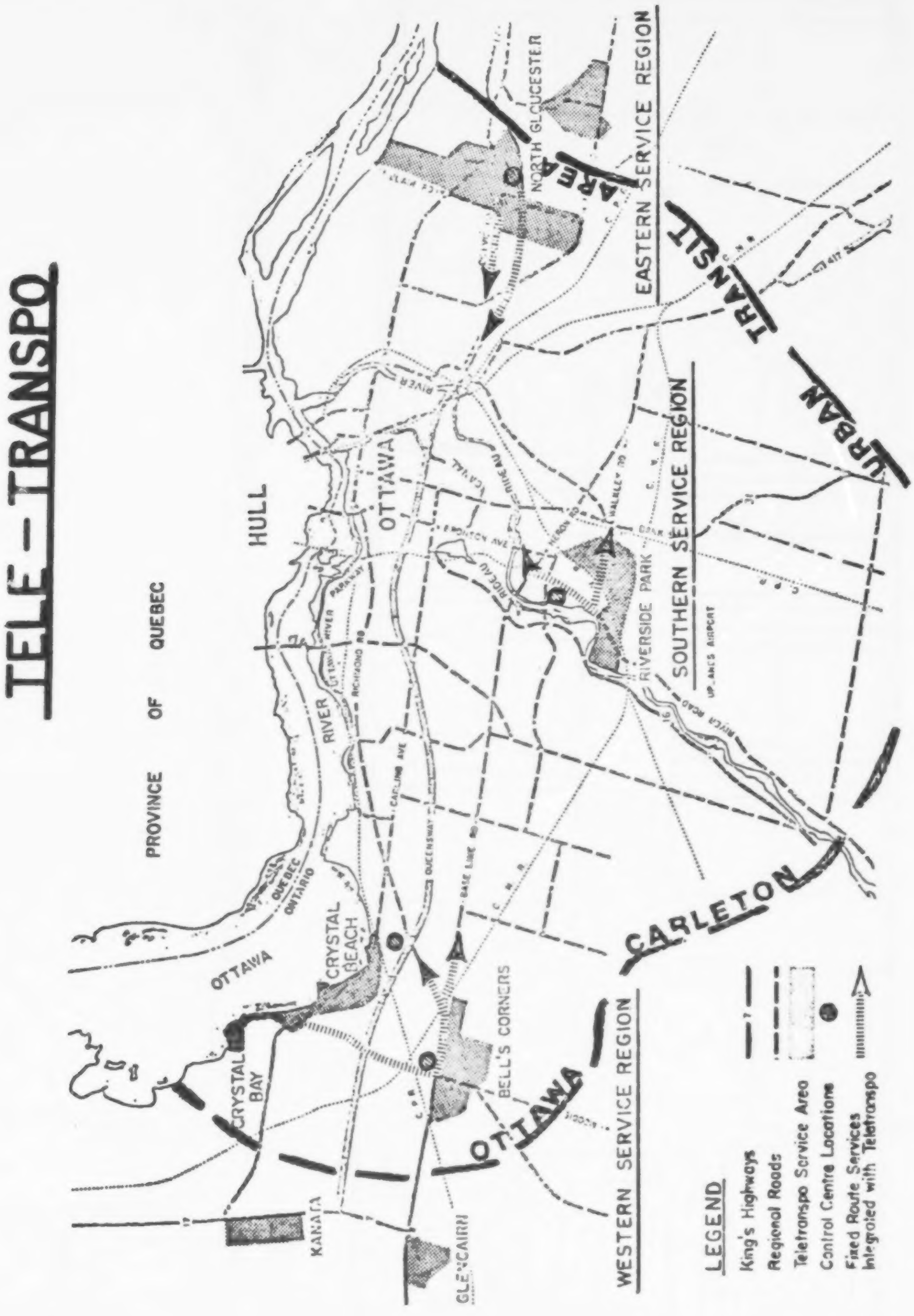
of which 90% are transportation costs and 10% are maintenance costs. During peak periods users are required to pay the regular transit fare plus a 25 c premium. The premium is reduced to 10 c in the off-peak. The mean deficit full service is $ 0.69/passenger carried.

+) Questions a) Capital Investment - track and b) Capital Investment - stops/stations, do not apply to the Tele-Transpo system as the system uses the normal street network and serves individual homes and established activity centers rather than stops or stations.

V. a) Pictures and Diagrams - Vehicle


24 PASSENGER SEATING — SMALL BUS TRANSIT INTERIOR
TYPICAL SEAT SECTION
12"
51"
20"
25"
34"
28"
13"
11"
35"
25"
17"
17"
5"

V. b) Pictures and Diagrams - Track (Switches) and Stations


TELE-TRANSPO
PROVINCE OF QUEBEC
HULL
OTTAWA
OTTAWA RIVER
QUEBEC
ONTARIO
CRYSTAL BAY
CRYSTAL BEACH
BELL'S CORNERS
KANATA
GLENCAIRN
NORTH GLOUCESTER
RIVERSIDE PARK
UPLANDS AIRPORT
RIDEAU RIVER
RIDEAU CANAL
RICHMOND RD
CARLING AVE
QUEENSWAY
BASE LINE RD
BRONSON AVE
RIVER ROAD
C.N.R.
C.P.R.
OTTAWA - CARLETON URBAN TRANSIT AREA
WESTERN SERVICE REGION
SOUTHERN SERVICE REGION
EASTERN SERVICE REGION
LEGEND
King's Highways
Regional Roads
Teletranspo Service Area
Control Centre Locations
Fixed Route Services Integrated with Teletranspo

Questionnaire for Short-Distance Transport Systems of Group: Bus

---

Name of System: articulated bus

type selected: MAN standard articulated bus type 890 SG

Name and Address of Manufacturer or Designer:

MAN (Maschinenfabrik Augsburg-Nürnberg)
8 München 50
Federal Republic of Germany

Area of Application:

public transport networks in cities in the FRG

State of Development by the End of 1974: operational

TECHNICAL DATA

I. Vehicles

---

a) Vehicle Description:

wheel-supported, self-propelled articulated vehicle

b) Vehicle Dimensions:

	length	16.70 m
	width	2.50 m
	height	3.00 m

c) Boarding and Alighting:

on one side; three double swing-in doors, each 1.25 m wide and 1.90 high;

height difference between vehicle floor and platform (=road) is 916 mm.

d) Vehicle Weight:

	curb weight	11,740 kg
	vehicle gross weight	22,215 kg

e) Materials:

vehicle body in light steel construction
chassis: steel structure
wheels: rubber-tyred (with air-inflated rubber tubes)

f) Passenger Accommodation:

50 passengers seated,

51 passengers standing, at a rate of 0.25 m^2/standing passenger (alternative version: 53 seats, 45 standing passengers).

all seats are arranged transversely, - 47 in direction of travel, 3 in opposite direction.

g) Air Conditioning:

heating: through motor heat or an additional unit operated with fuel oil (4.800 kcal/h)

ventilation: natural through windows and roof hatches

h) Support and Guidance Technique:

8 rubber wheels support and guide the vehicle; drive axle (= middle axle) is equipped with double tyres; wheel diameter 1000 mm); guidance is effected by steering and adhesion.

i) Propulsion:

Diesel combustion engine, 192 metric HP = 140 kW

k) Performance Data:

v_{max}= 90 km/h = 25 m/s

maximum take-off acceleration : 1.5 m/s^2

mean operational braking deceleration : 1.5 m/s^2

emergency braking deceleration : 5 m/s^2

maximum climbing ability at reduced speed : 7 %

II. Fixed Installations

---

a) Right-of-way: These buses use the normal city street network, sharing it in most cases with private transport.

b) Guideway Construction:

Streets and roads are usually covered with a bituminous course, rarely with a pavement.

gauge for front and rear axle 2045 mm

for dual axle in the middle 1800 mm

standard width for both carriageways not including safety space 7.0 m

minimum radius of curvature at 6 m/s 15 m

turning circle 22,5 m

c) Track Dimensions:

track width is identical with carriageway standard width; thickness of road surface: about 0.3 m.

d) Method of Switching/Weaving: ----

e) Stops and Stations:

on-line and off-line stations

length of platform = 20.0 m (maximum lenth for articulated buses is 18.0 m)

length of off-line lane (from branching-off to branching-in point) is 56.80 m

width of stop: 5.50 m

f) Control and Safety System:

no special safety technique (visual driving); in most cases, driving only with relative braking distance; monitoring and information via radio.

g) Power Supply:

on-board combustion for energy supply; energy store = fuel tank for 200 l Diesel.

III. Operation

---

a) Mode of Operation:

fixed routes and fixed stops; or stopping upon request

b) Nature and Frequency of Service:

scheduled operation with variable time cycles during the day; waiting times due to non-familiarity with time-table or traffic-related irregularities.

c) Type and Number of Coupled Vehicles:

coupling of vehicles is not possible

d) Maximum Holding Capacity (at a rate of 0.25 m^2 per standee)

101 passengers

e) Carrying Capacity (at a rate of 0.25^2 per standee)

maximum theoretical capacity : 12,000 pass/h in each direction at a vehicle headway of 30 s

maximum practical capacity : ca. 8,500 pass/h in each direction

---

IV. Costs/Capital Requirements

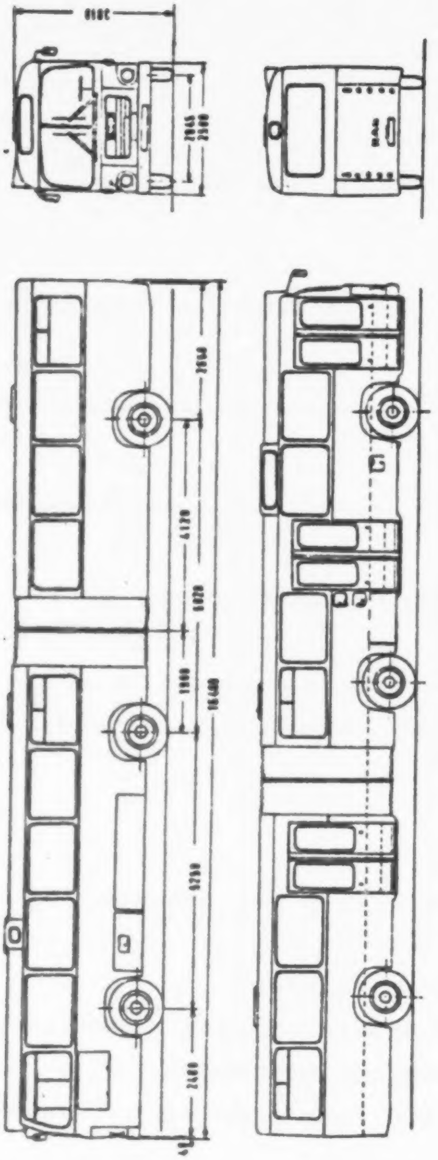
---

a) Capital investment - track: DM 100,000 per km of double lane

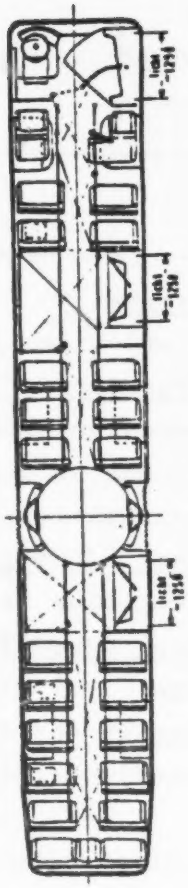
b) Capital investment - stop : DM 25,000 per stop

c) Capital investment - vehicle: DM 220,000 per vehicle (mean life-time about 7 years)

V. a) Pictures and Diagrams of Vehicles

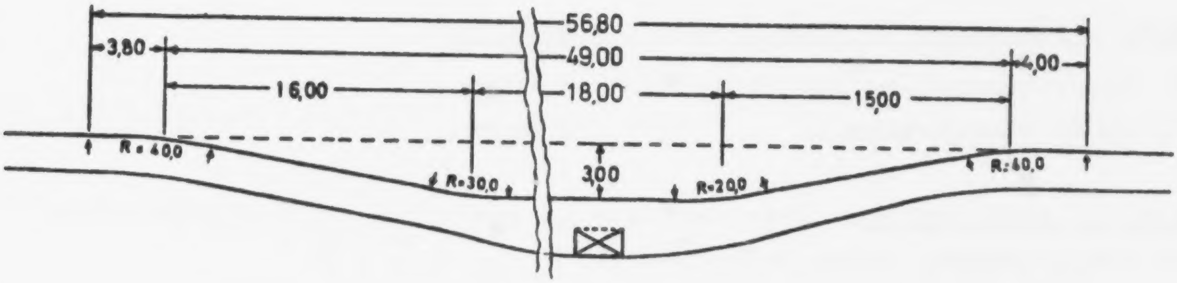


Front, rear and side view of vehicle



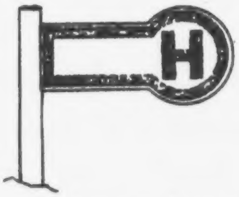
Plan view and seat arrangement

V. b) Pictures and Diagrams of Track (Switches) and Stations

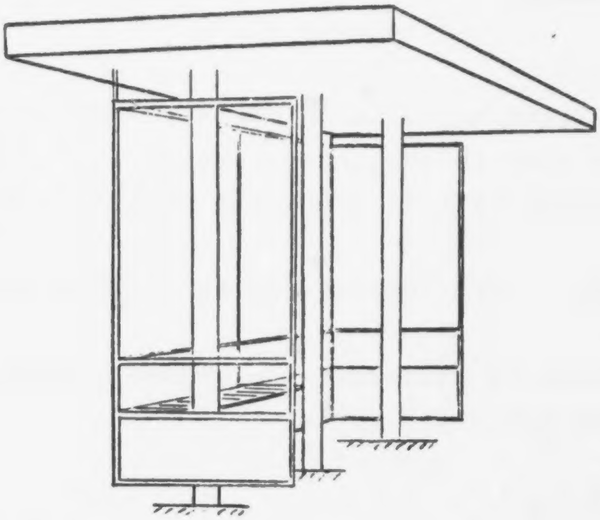

56,80
3,80
49,00
4,00
16,00
18,00
15,00
R=40,0
R=30,0
3,00
R=20,0
R=40,0

approach speed v = 30 kmh

Plan view of an off-line station



Characteristic mark for a bus stop conforming to law (FRG)



Shelter

Questionnaire for Short-Distance Transport Systems of the Group: Track-Guided Small Cabin Systems

---

Name of System: CAT (Cabinentaxi) or C-Bahn

Name and Address of Manufacturer or Designer:

1. Messerschmitt-Bölkow-Blohm GmbH, 8 München 80, FRG
2. DEMAG Fördertechnik, 58 Hagen, FRG

Area of Application: Test facility in operation at the DEMAG plant at Wetter-Hagen, since September 1973

State of Development by the End of 1974:

Testing and trials with various vehicle prototypes on a 1300 m test track. Additional test tracks, stations and vehicles are prepared

---

TECHNICAL DATA

I. Vehicles

---

a) **Vehicle Description:** Rail-mounted and suspended vehicles; single power cars for one-ended operation

b) **Vehicle Dimensions:** +) length: 2.3 m , width (1.6)m,
height: (1.5) m

c) **Boarding and Alighting:** Sliding doors on both sides, about 145 cm high and 75 cm wide in the lower part;
difference between vehicle floor and platform level: 150 mm

d) **Vehicle Weight:** curb weight: 750 kg; gross weight 1,050 kg

e) **Materials:** Frame of passenger compartment: aluminium hollow section
wheels: solid rubber

+) figures in paranthesis apply to cabin only, not including running unit

f) Passenger Accommodation: 3 seated passengers
0 standing passengers (at 0.25 m^2 per standee);
all seats are arranged transversely, facing the direction of travel.

g) Air Conditioning: ./.
heating: thermostatically controlled (supplied with mains current)
ventilation: natural and artificial

h) Support and Guidance Technique:

The track-mounted vehicle is supported by 4 vertically arranged solid rubber wheels, the track suspended vehicle by 8 solid rubber wheels; guidance is provided by 4 + 2 horizontally arranged solid rubber wheels.

For switching, two of four horizontally arranged wheels together with 2 horizontal guide wheels envelope the guide rail.

i) Propulsion: electric propulsion provided by two asynchronous double-sided sandwich motors

power input at nominal thrust	36 kVA
power input for starting thrust	113 kVA

phase-shifting control by means of thyristors

k) Performance Data:

v_{max} = 36 km/h = 10 m/s

maximum take-off acceleration	: 2.5 m/s^2
mean take-off acceleration up to 10 m/s	: 2.5 m/s^2
mean operational braking deceleration	: 2.5 m/s^2
emergency braking deceleration	: 5.0 m/s^2
maximum climbing ability at 10 m/s	: 10 %
maximum climbing ability at reduced speed	: 15%

II. Fixed Installations

a) Right-of-way: mainly aerial; separate and exclusive right-of-way indispensable for operation

b) Guideway Construction: Guideway girder in steel or concrete; distances between supports about 40 m.
Track guidance elements: steel rails serving as running surface for vertical and horizontal wheels

gauge:	1300 mm	for top-riding vehicle
	900 mm	for suspended vehicle

standard clearance for both directions of travel not including safety space	4.88 m
smallest radius of curvature at 10 m/s	30 m

c) Track Dimensions: Track girder with integrated support and guide rails, power rail, secondary for LIM etc.
track dimensions for system operating top-riding and suspended vehicles: width : 1,60 m
height: 1.75 m

d) Method of Switching: passive switches; vehicle-mounted switching device and switch wheels.

e) Stops and Stations: off-line stations
length of platform about 14 m with 4 dispatch positions
length of off-line track (from branch-off point to branch-in point) about 100 m including station;
width of station: 8.80 m including one lateral platform and the two tracks (off-line and through track).

f) Control and Safety System: automatic surveillance and control of vehicles; headway control by means of an attenuation measurement system, assisted by a redundant speedometer system.

g) Power Supply: conductor rail with 50 Hz three-phase current; 500 Volt; lateral power collection.

III. Operation

a) Mode of Operation: no fixed routes, fixed stops; origin-to-destination journeys without intermediate stops.

b) Nature and Frequency of Service: demand-actuated operation; immediate availability of service during peak hours as well as during off-peak hours (short waiting times may occur during peak-hour traffic due to the temporary non-availability of empty cabins).

c) Type and Number of Coupled Vehicles: no coupling possible

d) Maximum Holding Capacity (at 0.25 m^2 per standee):

3 seated passengers

e) Carrying Capacity:

maximum theoretical capacity:	8,100 passengers/hour in each direction at a vehicle headway of 1.3 s
maximum practical capacity:	about 4,500 passengers/hour in each direction

---

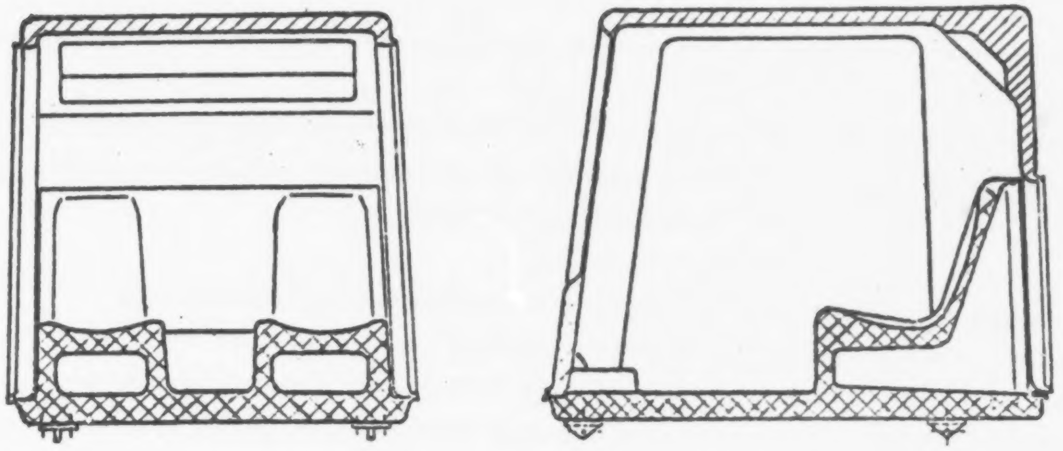
IV. Costs/Capital Requirements

a) Capital investment - track: 6,000,000 DM/km, including station based on a distance between stations of 700 m

b) Capital investment - station: 200,000 DM/station

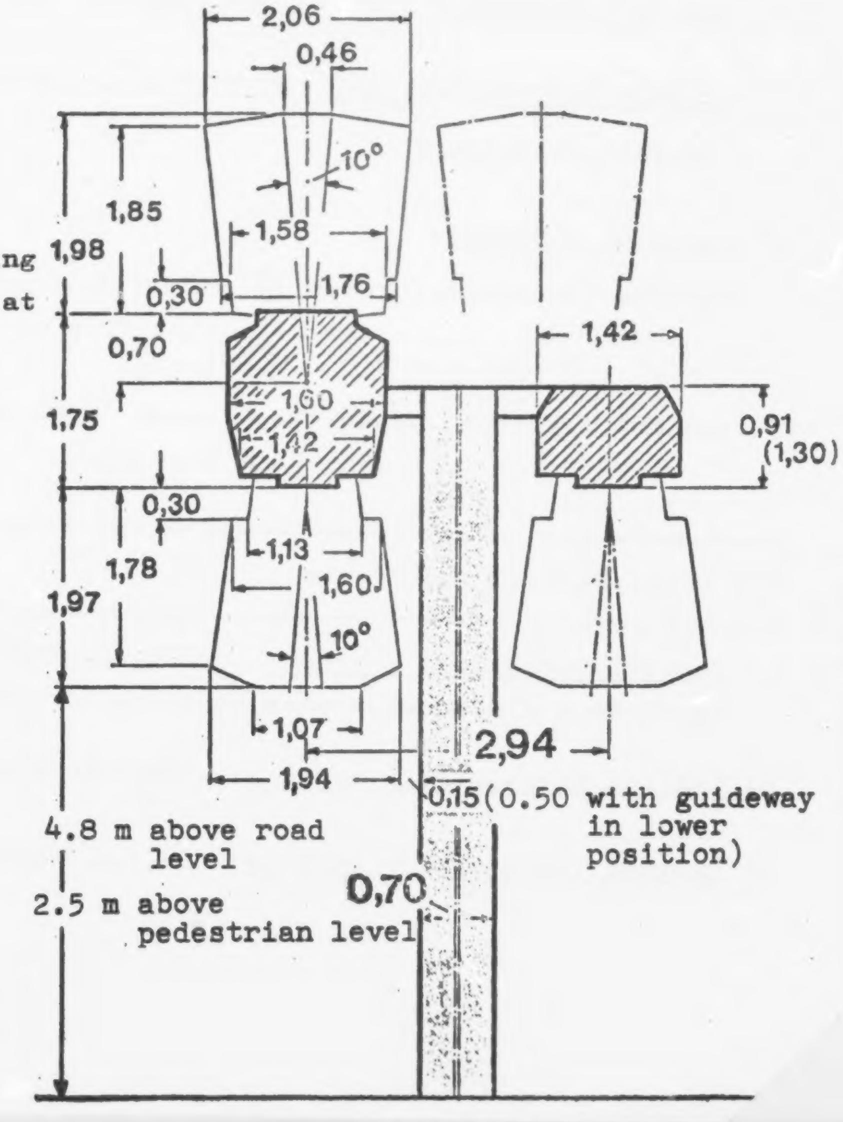
c) Capital investment - vehicle: 22,000 DM/vehicle

V. a) Pictures and Diagrams - Vehicle

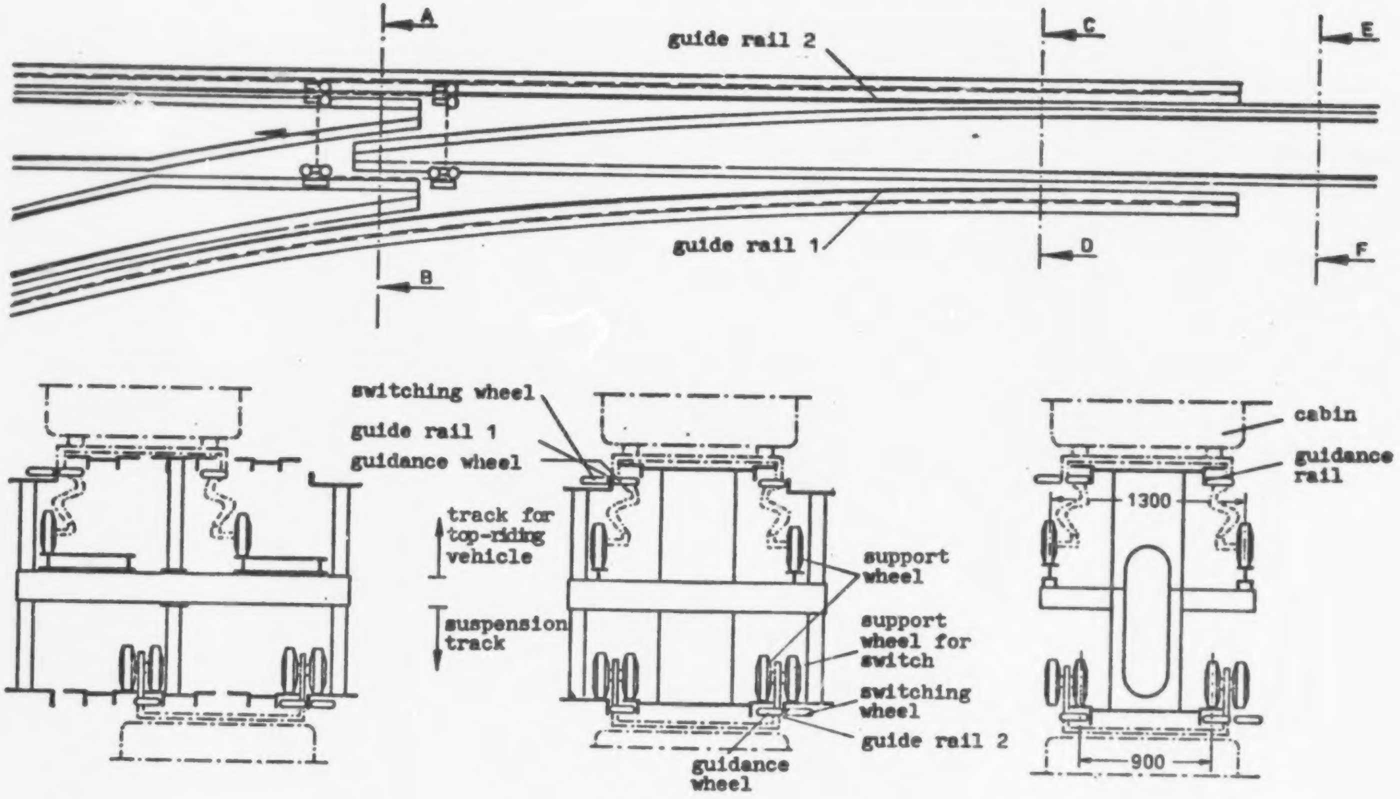


Longitudinal and cross section of cabin

Arrangement of top-riding and suspended vehicles at guideway girder (profiles of vehicle and guideway)


2,06
0,46
10°
1,85
1,98
1,58
1,76
0,30
0,70
1,42
1,60
1,42
1,75
0,91
(1,30)
0,30
1,13
1,78
1,60
1,97
10°
1,07
2,94
1,94
0,15 (0.50 with guideway in lower position)
4.8 m above road level
2.5 m above pedestrian level
0,70

V. b) Pictures and Diagrams - Track (Switches) and Stations


A
B
C
D
E
F
guide rail 2
guide rail 1
switching wheel
guide rail 1
guidance wheel
track for top-riding vehicle
suspension track
support wheel
support wheel for switch
switching wheel
guide rail 2
guidance wheel
cabin
guidance rail
1300
900

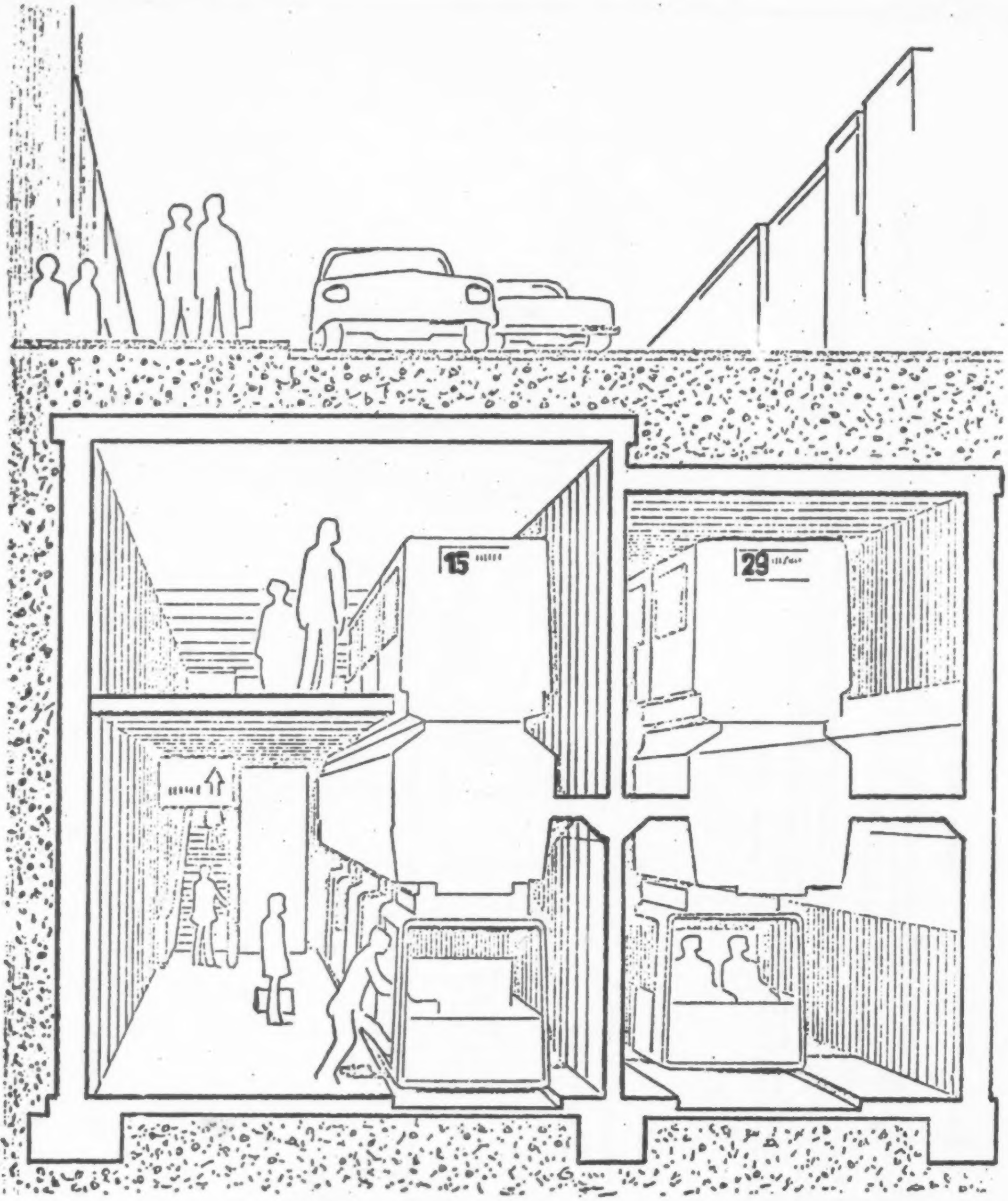
Section A-B

Section C-D

Section E-F

Support and Guidance System of Switch Points

V. b) Pictures and Diagrams - Track (Switches) and Stations



Underground station

Questionnaire for Short-Distance Transport Systems of the Group: Track-Guided Large Cabin Systems

---

Name of System: H-Bahn (acronym for Hänge-Bahn = suspension system)

Name and Address of Manufacturer or Designer:

1. Siemens AG, 852 Erlangen, FRG
2. Waggonfabrik Uerdingen AG, 415 Krefeld-Uerdingen, FRG

Area of Application:

Running tests on an experimental guideway girder; 150 m guideway including switches established on the premises of Waggonfabrik Uerdingen at Düsseldorf since autumn 1974.

State of Development by the End of 1974:

Testing facility planned to be established at the Siemens plant in 1975/76.

TECHNICAL DATA

I. Vehicles

---

a) **Vehicle Description**: suspended vehicle system; single power cars for two-ended operation.

b) **Vehicle Dimensions**:

length:	3.5 m;	width:	2.3 m;	height:	2.57 m;
cabin only: length:	3.5 m;	"	2.3 m;	"	2.3 m;

c) **Boarding and Alighting**: double sliding doors on both sides of cabin; width: 1.7 m; height: 1.9 m
difference between vehicle floor and platform level: about 50 mm.

d) **Vehicle Weight**: curb weight: 2,800 kg; gross weight: 4,000 kg

e) **Materials**: cabin: plastic material
running unit: aluminium frame
wheels: steel wheels, probably fitted with a plastic bandage

f) Passenger Accommodation: 8 seated passengers
8 standing passengers (at a rate of 0.25 m^2 per standee)

4 single seats are arranged in a row, transversely, facing the direction of travel, 4 facing the opposite direction.

g) Air Conditioning: ./.

heating: thermostatically controlled (supplied exclusively with mains current)
ventilation: probably by motor-driven fans and natural ventilation.

h) Support and Guidance Technique:

Support is provided by the running treads of two centrally flanged steel wheels; guidance is provided by the central wheel flange in combination with horizontal guide wheels running along two guide rails in the girder, plus the lateral force of the LIM.

Switching: unilateral magnetic pull by the synchronous linear motor; additional safety is provided by a toggle mechanism acting on the safety rail during the switching process.

i) Propulsion: electric drive provided by 2 single-sided homopolar (synchronous) linear motors; control of acceleration and electric brakes is effected by fixed frequency converters incorporated in the station track.

k) Performance Data:

v_{max} = 36 km/h = 10 m/s

maximum take-off acceleration	: 1,75 m/s^2
mean take-off acceleration up to 10 m/s	: 1.25 m/s^2
mean operational braking deceleration	: 1.25 m/s^2
mean emergency braking deceleration	: 2.5 m/s^2
maximum climbing ability up to 10 m/s	: 15 %

II. Fixed Installations

a) Right-of-way: mainly aerial (due to suspension system).

b) Guideway Construction: Probably closed box girder with incorporated support rails and separate center rails which are unilaterally interrupted in the switch area; for safety reasons, auxiliary rails are provided. Furthermore, the box girder incorporates the live rails, the reaction rails of the LIM and the communication cables.

Distance between the centres of the double track	4.5 m
standard clearance for both directions of travel	6.5 m
including a safety space of 2 x 0,30 m + 0.70 m (support)	
smallest radius of curvature at 10 m/s	40 m
and at about 2 m/s in depot areas	20 m

c) Track Dimensions:
as a closed box girder: width: 0.75 m
height: 0.95 m
height of supports h = 9.57 m above road level

d) Method of Switching: passive switches with a design length of about 22.5 m and a minimum radius of about 60 m; LIM exerts unilateral pull in the desired direction; for additional safety in the event of power failure, a toggle mechanism acts on the safety rail.

e) Stops and Stations: off-line stations
length of platform: approx. 12 m
length of off-line track (from branch-off point to branch-in point): 168.4 m for 3+3+3 positions
width of station: 13.70 m for one lateral platform and the two tracks (off-line and through track).

f) Control and Safety Technique: fully automated headway control through constant speed (synchronous drive), assisted by a short block signal system (length of block: 7.5 m); transmission of information via wayside conductors; control provided by station computer; central computer controls cabin turn-round.

g) Power Supply:

On each side of guideway girder there are four live rails, 380 V three-phase current; no voltage and frequency regulation on open track; in stations regulation by means of converters in the off-line track.

III. Operation

a) Mode of Operation: fixed routes; limitation of intermediate stops.

b) Nature and Frequency of Service: demand-actuated operation; short waiting times during peak hours, longer waiting times during off-peak hours - no accurate calculation of waiting times possible.

c) Type and Number of Coupled Vehicles: 3 cars (power cars) mechanically and electrically coupled.

d) Maximum Holding Capacity (at a rate of 0.25 m^2 per standee): 48 seated and standing passengers

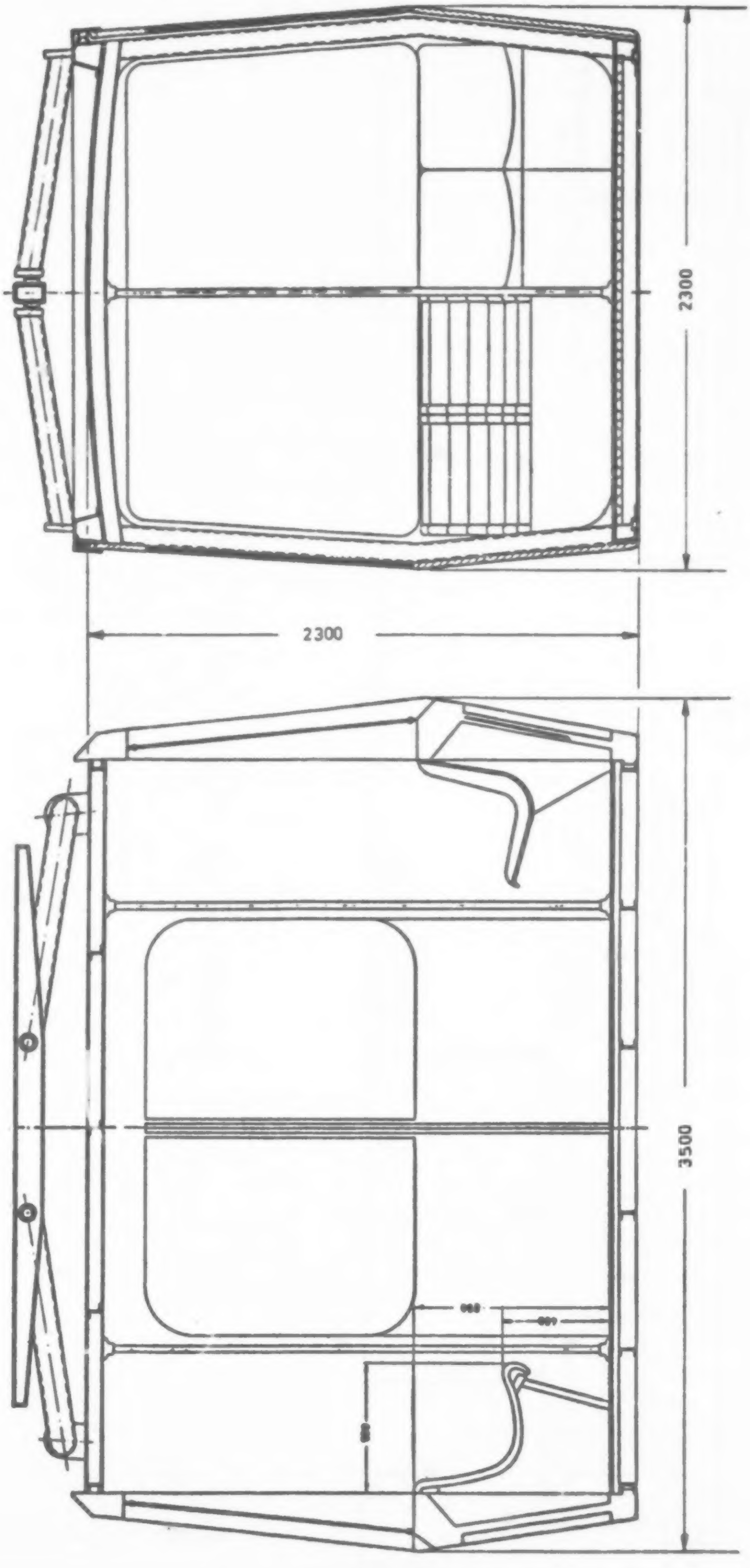
e) Carrying Capacity:

maximum theoretical capacity:	17,000 passengers/hour in each direction at a vehicle headway of 10 s
maximum practical capacity:	8,000 passengers/hour in each direction.

IV. Costs/Capital Requirements

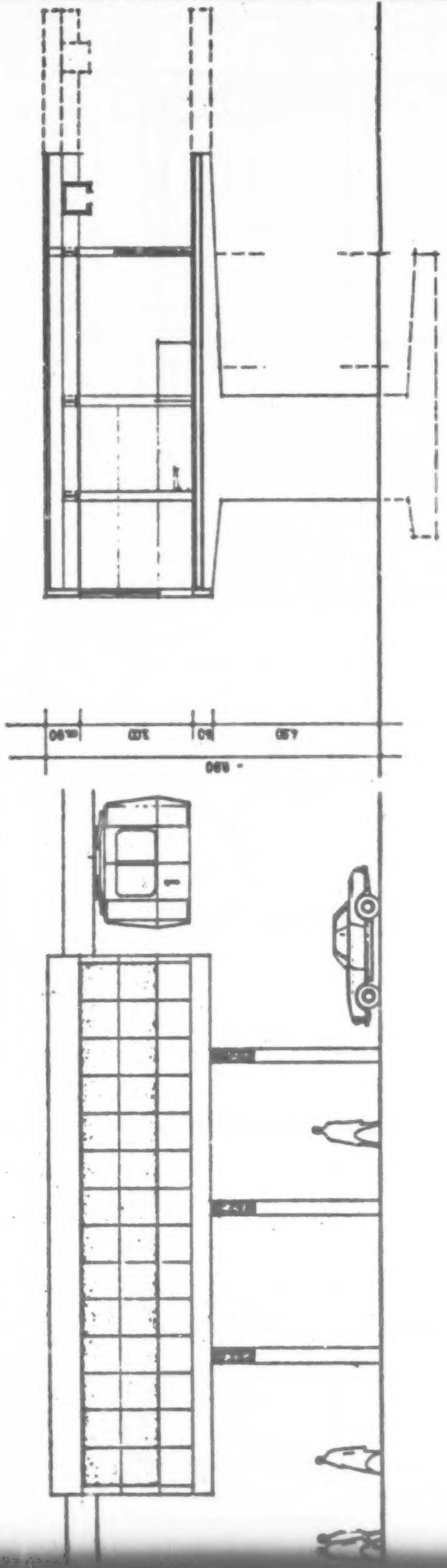
a) Capital investment - track:	approx. 6,000,000 DM/km of double track including supports but excluding stations
b) Capital investment - station:	230,000 DM/station, not including power supply and tracks
c) Capital investment - vehicle:	approx. 60,000 DM/vehicle.

V. a) Pictures and Diagrams - Vehicle


2300
2300
3500

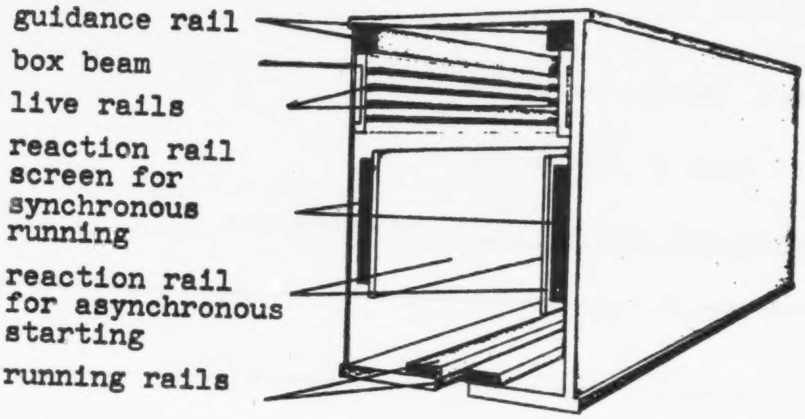
Longitudinal and Cross Section of Cabin

V. b) Pictures and Diagrams - Track (Switches) and Stations

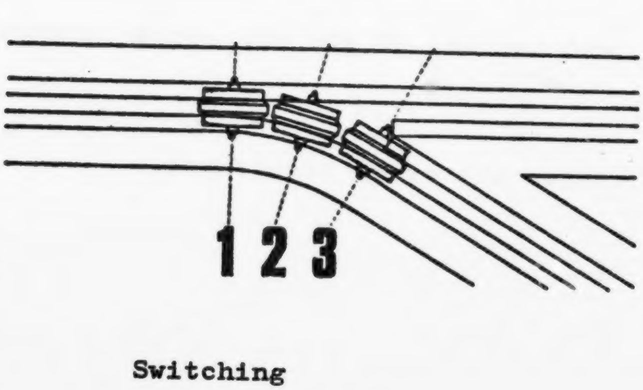


Plan View and Cross Section of Station

V. b) Pictures and Diagrams - Track (Switches) and Stations


guidance rail
box beam
live rails
reaction rail screen for synchronous running
reaction rail for asynchronous starting
running rails

Track girder



Switching

Questionnaire for Short-Distance Transport Systems of the Group: Track-Guided Large-Capacity Systems

---

Name of System: Tramway (streetcar)

Name and Address of Manufacturer or Designer:

1. Beynes, Netherlands
2. Werkspoor, Netherlands
3. Linke Hofmann Busch, Salzgitter, FRG

Area of Application: City of Amsterdam

State of Development by the End of 1974: in operation

TECHNICAL DATA

I. Vehicles

---

a) **Vehicle Description:**

Rail supported vehicle, 8-axled articulated powered car for one-ended operation.

b) **Vehicle Dimensions:** length: 24.2 m; width: 2.34 m; height: 3.20 m;

c) **Boarding and Alighting:**

on one side only; two double swing-in doors, plus 3 single swing-in doors;
width of doors: 750 mm / 1440 mm;
height of doors: 1900 mm;
difference between vehicle floor and platform: 875 mm

d) **Vehicle Weight:** curb weight: 30,200 kg; gross weight: 44,000 kg;

e) **Materials:**

Vehicle body and bogies are steel structures.

f) Passenger Accommodation: 64 seated passengers
85 standing passengers (at a rate of 0.25 m^2 per standee)

63 seats are arranged transversely, facing the direction of travel, 1 seat is arranged transversely, facing the opposite direction, plus 5 longitudinally arranged rumble seats in the rear

g) Air Conditioning: ./.

heating: thermostatically controlled (supplied with energy lost through rolling and braking resistances; additional energy supply of 7 kW per vehicle unit from mains current)

ventilation: air exchange (35 - fold) through roof ventilators; after cooling of resistors exhaust air is blown below vehicle; additional hinged windows on door side only.

h) Support and Guidance Technique:

4 bogies with 8 axles and 16 rubber spring - one ring steel wheels (wheel diameter 668/598 mm) ; guidance is provided by conical wheel treads and the wheel flanges.

Switching: guidance provided by the wheel flanges along the direction determined by the guideway.

i) Propulsion:

4 electric rotary motors for individual axle drive, each with a power rating of 53 kW; camshaft gear; electromagnetic relays; electronic, semi-automatic control (Simatic).

k) Performance Data:

v_{max} = 60 km/h = 16,7 m/s

mean take-off acceleration	:	1.2 m/s^2
operational braking deceleration	:	1.7 m/s^2
emergency braking deceleration	:	4 m/s^2
maximum climbing ability at reduced speed	:	4 %.

II. Fixed Installations

a) Right-of-way: one line is operated nearly exclusively on a separate right-of-way; the other lines will be progressively separated from private traffic.

b) Guideway Construction: Where right-of-way is shared with private transport permanent way is fitted with grooved rails; otherwise track is equipped with flat-bottom rails (Vignole rails) on a ballast bed and sleepers.

Track guidance elements: rail head, guide rails, switch blades and check rails.

gauge: 1,435 mm

Standard clearance for both directions of travel without safety space :	5.30 m
smallest radius of curvature at 5.6 m/s:	17.5 m

c) Track Dimensions:

Width generally identical with standard clearance (as indicated above); height is determined by the nature of the road bed (ballast bed: approx. 0.5 m).

d) Method of Switching:

Active switches; rail switches with rigid frogs, stock rails and tongue rails as well as check rails (for flat-bottom rails).

e) Stops and Stations:

on-line stations

length of platform: 55 m

width of station: 4.05 m including one lateral platform plus the track.

f) Control and Safety Technique:

No special safety technique (visual driving); surveillance and information via radio; experimental operation of an inductive car signalling system designed to actuate, among other things, switches and traffic lights.

g) Power Supply:

Overhead power supply with 600 V d.c.; power collection by means of a double-bar pantograph with double bow.

III. Operation

---

a) Mode of Operation: fixed routes and fixed stops; stop only upon request.

b) Nature and Frequency of Service:

Scheduled operation (time-tables) with variable time cycles in the course of a day; waiting times due to passengers' non-familiarity with time-table or to operational irregularities.

c) Type and Number of Coupled Vehicles:

Coupling of vehicles is not provided for

d) Maximum Holding Capacity (at 0.25 m^2 per standee):

149 passengers

e) Carrying Capacity:

Maximum theoretical capacity : 8,940 passengers/hour in each direction at a vehicle headway of 60 s.

Maximum practical capacity : approx. 7,000 passengers/hour in each direction

The theoretical capacity is reduced by 20% owing to inevitable irregularities of operation and uneven load factors.

IV. Costs/Capital Requirements

---

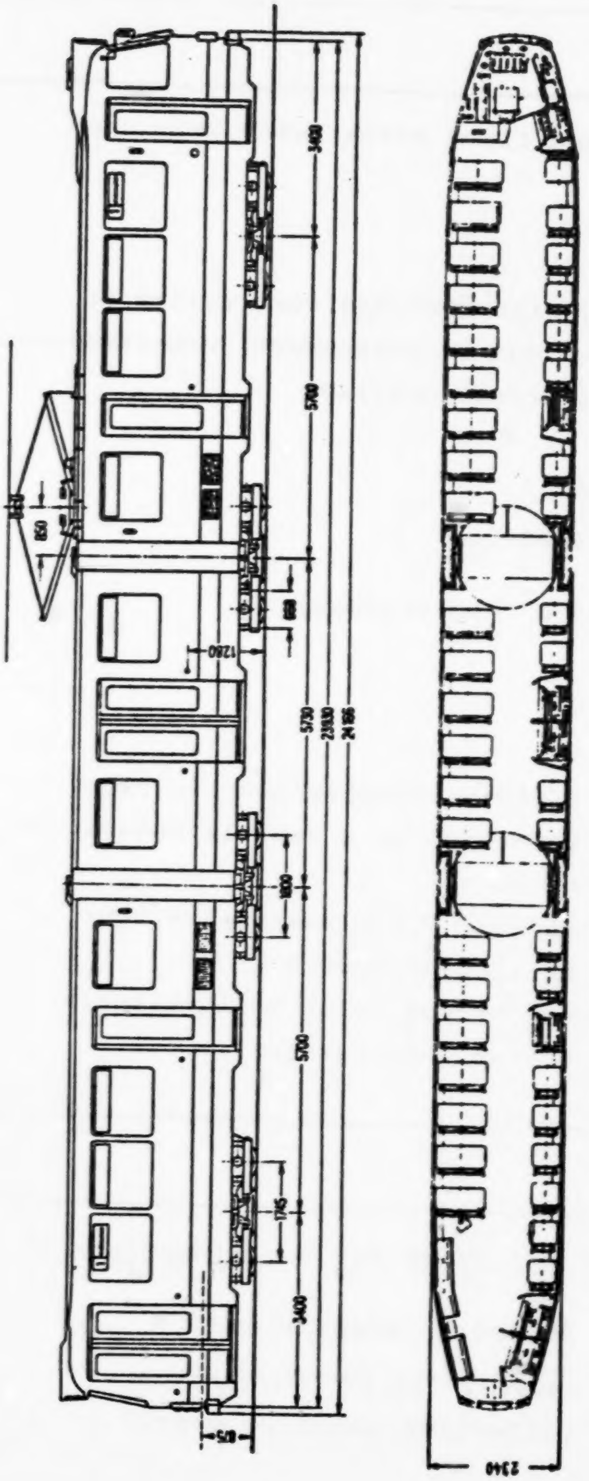
a) Capital investment - track: 1.2 Mio DM/km for two directions +)

b) Capital investment - stations: 30,000 DM/stop-island+)

c) Capital investment - vehicle: approx. 730,000 DM/vehicle (life-time about 20 years)

+) Values, if right-of-way is shared with private traffic

V. a) Pictures and Diagrams - Vehicle


3400
5700
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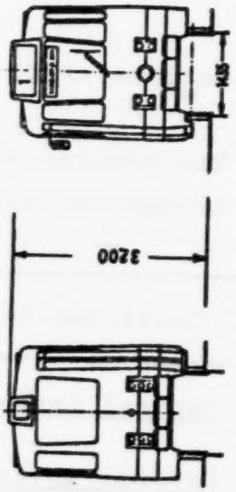
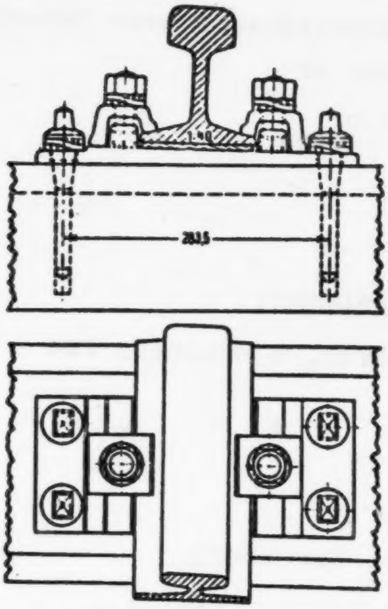
23380
24166
1260
880
850
1800
1745
3400
675
2340

Lateral and Plan View, Seating Arrangement

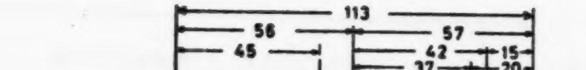


Front and Rear View

V. b) Pictures and Diagrams - Track (Switches) and Stations



Method of fastening a Vignole rail on a wooden sleeper


113
56
57
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42
15
37
20
35
22
5
33
40,8
9
10
3
5,7
15
1:6
1:6
1:6
47
49,6
5
10
20
12
12
35
28,6
1:5
10
R=225
180
12
93,6
10
10
1:10
1:10
8
17
2
13,7
180

Grooved rail with 35, 37, or 42mm width of the groove

(Measures in mm)

Annex 3

Questionnaire for Short-Distance Transport Systems of the Group: Track-Guided Large Capacity Systems

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Name of System: Schnellbahn/U-Bahn (unterirdische oder Unterpflasterbahn)
(= rapid transit railway or
underground railway or
Metropolitan)

selected type: A 2/Munich

Name and Address of Manufacturer or Designer:

1. Waggon- und Maschinenfabrik Donauwörth, 8 München, FRG
2. MAN, 85 Nürnberg, FRG

and others

Area of Application:
Munich, same version also operated in Nuremberg

State of Development by the End of 1974: in operation

TECHNICAL DATA

I. Vehicles

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a) **Vehicle Description:** Rail mounted vehicle; one unit consisting of a married pair of powered cars for two-ended operation.

b) **Vehicle Dimensions:** length: 37.15 m; width: 2.90 m; height: 3.55 m;

c) **Boarding and Alighting:**

6 double swing-slide doors on each side, each 1300 mm wide and 1900 mm high;
difference between vehicle floor and platform: about 100mm

d) **Vehicle Weight:** curb weight: 51,600 kg; gross weight: 82,850 kg

e) **Materials:** vehicle body: aluminium alloy structure
bogies: steel

f) **Passenger Accommodation:** 98 seated passengers
192 standing passengers (at a rate of $0.25\ m^2$ per standee)
double seats only; 50 % are arranged transversely, facing the direction of travel, 50 % facing the opposite direction.

g) **Air Conditioning**: ./.

heating: thermostatically controlled
ventilation: natural (through roof ventilators and windows)

h) **Support and Guidance Technique**:

4 bogies with 8 axles and 16 steel wheels (wheel diameters 900/820 mm); guidance is provided by conical wheel treads (side motion) and wheel flanges.
Switching: guidance is provided by the wheel flanges along the direction determined by the guideway.

i) **Propulsion:** electric rotary motor; every two axles driven by a longitudinal motor; d.c. motors; power rating 4 x 180 kW, double camshaft gear.

k) **Performance Data**:

v_{max} = 80 km/h = 22.2 m/s

maximum take-off acceleration	$1.28\ m/s^2$
mean take-off acceleration up to 12.5 m/s	$1.12\ m/s^2$
operational braking deceleration	$1.28\ m/s^2$
emergency braking deceleration	$1.28\ m/s^2$
maximum climbing ability at reduced speed	4 %

II. Fixed Installations

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a) **Right-of-way**: mainly in tunnel

b) **Guideway Construction**: permanent way built with ballast bed and sleepers; fitted with flat-bottom (Vignole) rails; lateral power rail;
track guidance elements: rail head, guide rails, switch blades and check rails.
gauge : 1 432 mm
standard clearance for double track (both directions of travel) 7.10 m

including a safety space of	0.70 m
minimum radius of curvature (under operational restrictions)	70 m
minimum radius of curvature on open track	300 m

c) Track Dimensions:

Width generally identical with standard clearance; height is determined by the nature of the road bed (ballast bed approx. 0.50 m).

d) Method of Switching:

Conventional rail switches with rigid frogs, stock rails and tongue rails as well as check rails.

e) Stops and Stations: on-line arrangement

length of platform:	120 m
width of station	~ 7.50 m including one lateral platform and one track

f) Control and Safety Technique: wayside conductors (fixed signal blocks) for normal operation; in exceptional cases, operation with fixed light signals; inductive train control; dead man device; radio surveillance and information system.

g) Power Supply: live rail with 750 V d.c.; power collection from below live rail; system-owned sub-stations spaced at about 2.5 km.

III. Operation:

---

a) Mode of Operation: fixed routes and fixed stops; stop at each station.

b) Nature and Frequency of Service:

Time-table operation with variable time cycles in the course of a day.

c) Type and Number of Coupled Vehicles:

Three married pairs of powered cars up to a total length of 111,45 m.

d) Maximum Holding Capacity (at 0.25 m^2 per standee):

870 passengers

e) Carrying Capacity:

Maximum theoretical capacity	: 34,800 passengers/hour in each direction at a vehicle headway of 90 s
maximum practical capacity	: 25,000 passengers/hour in each direction.

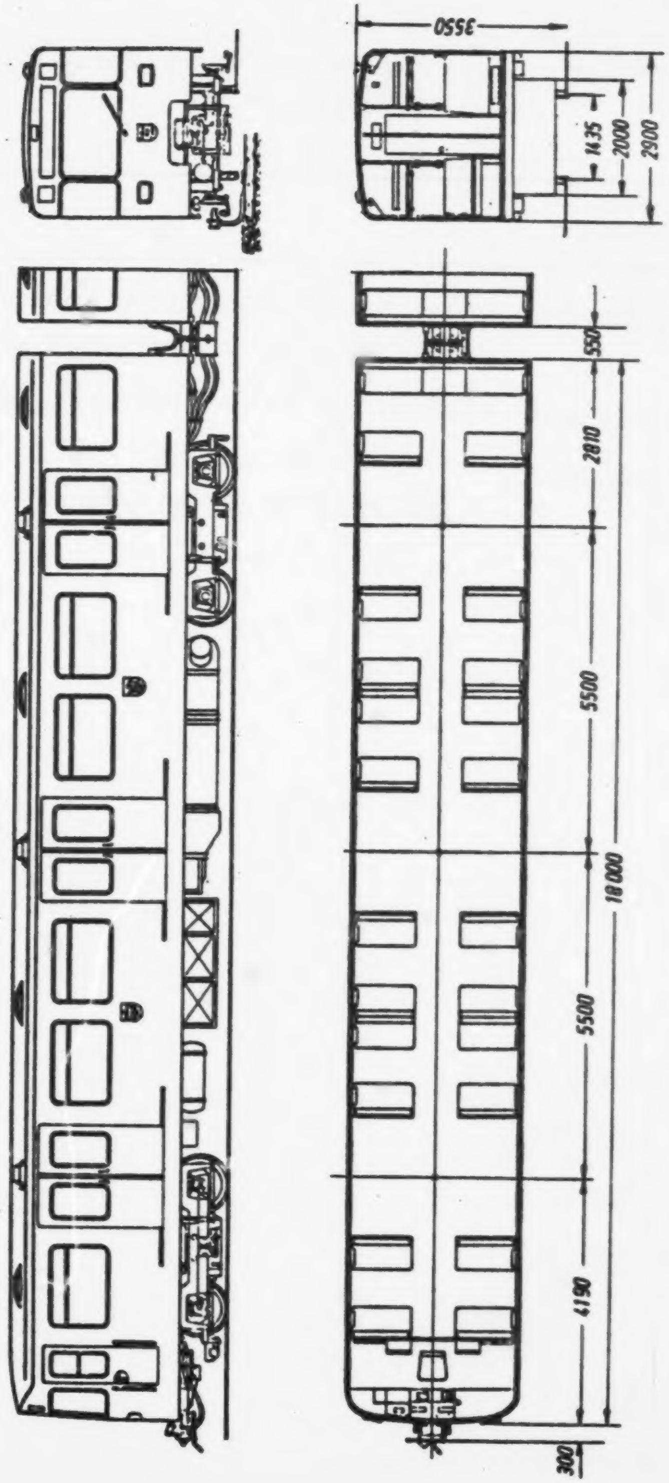
IV. Costs/Capital Requirements

a) Capital investment - track: approx. 50,000,000 DM/km of double track, including underground stations

b) Capital investment - station: approx. 10,000,000 DM/station

c) Capital investment - vehicle: 1,200,000 DM/vehicle (life-time about 30 years)

V. a) Pictures and Diagrams - Vehicle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550
2810
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5500
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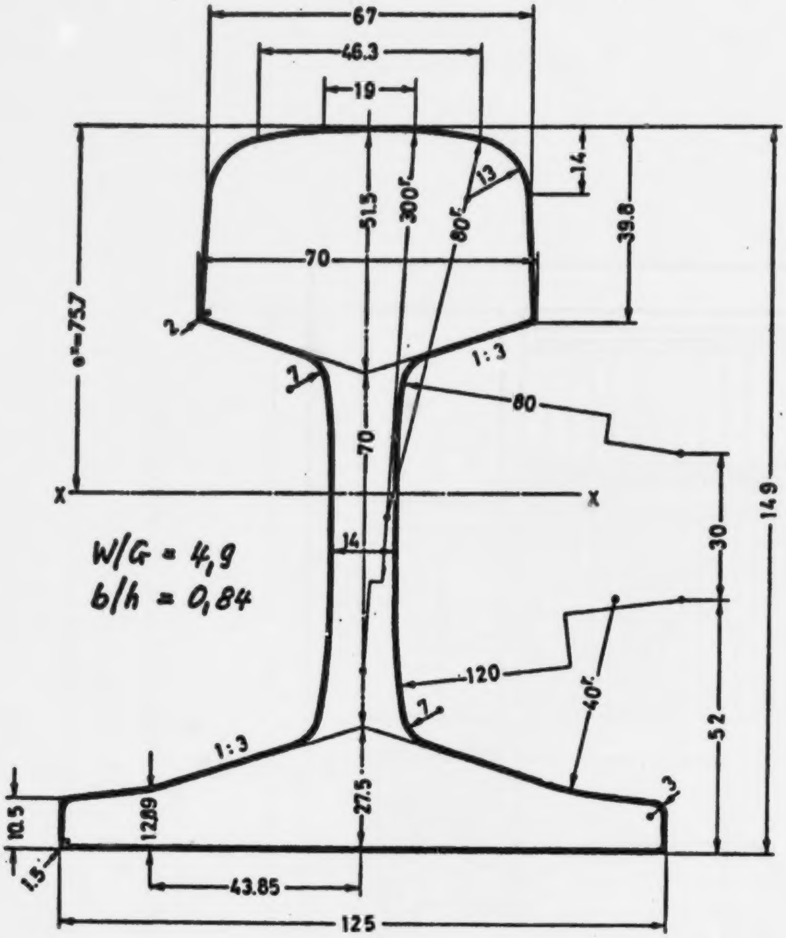
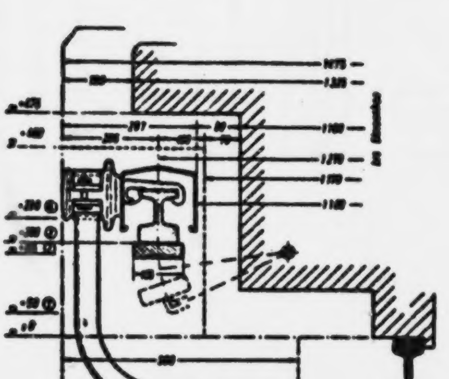
4190
300

Lateral, Front and Plan View, Cross Section and Seating Arrangement

V. b) Pictures and Diagrams - Track (Switches) and Stations


67
46.3
19
14
13
51.5
300r
80r
39.8
70
e1=75.7
2
1
1:3
80
70
x
x
30
149
14
W/G = 4,9
b/h = 0,84
120
1
40r
52
1:3
3
10.5
12.89
27.5
1.5
43.85
125

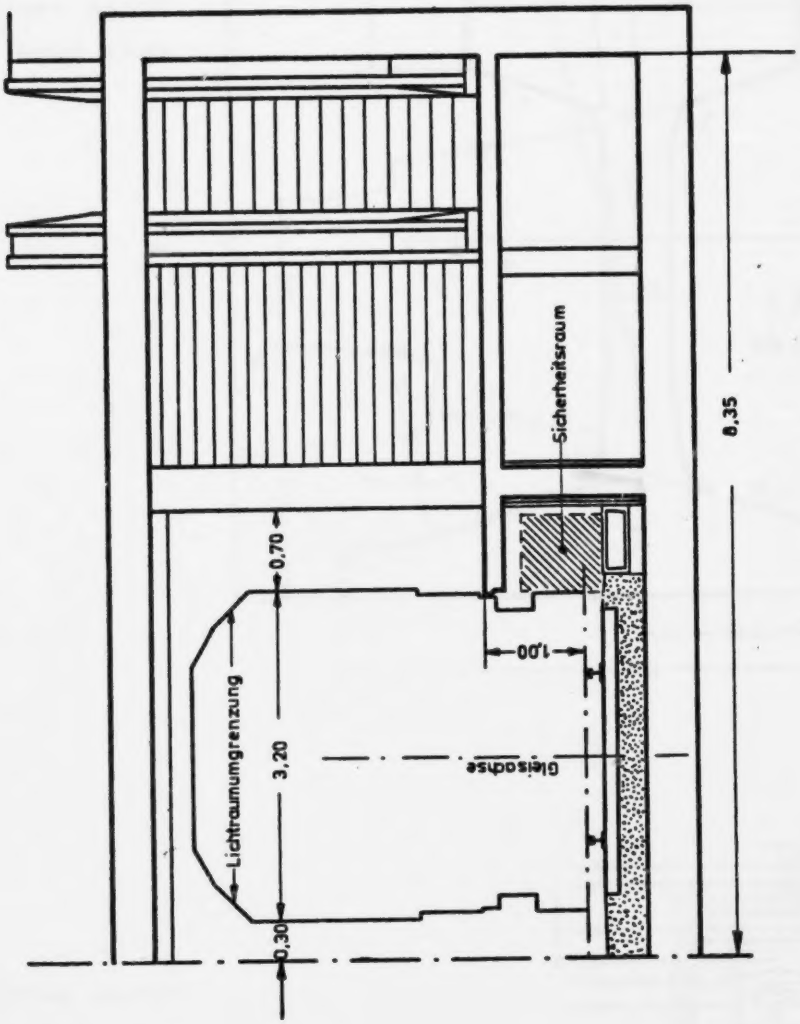
Cross section of rail type S 49



Cross section illustrating the arrangement and protection of a live rail

V. b) Pictures and Diagrams - Track (Switches) and Station

CROSS SECTION OF A STATION WITH LATERAL PLATFORM


Sicherheitsraum
8,35
0,70
3,20
0,30
1,00
Lichtraumumgrenzung
Gleisachse

Lichtraumumgrenzung: maximum moving dimensions
Gleisachse: rail axle
Sicherheitsraum: safety space